Surface Water Monitoring and Assessment
1998 Lake Erie Report

Featuring a summary of tributary and nearshore conditions and trends for the Lake Erie basin.

Environmental Monitoring and Reporting Branch

Ontario

Ministry of the Environment

Foreword

*The **Surface Water Monitoring and Assessment 1998 Annual Report** has been prepared to summarize the range of recent surface water monitoring work undertaken by the Environmental Monitoring and Reporting Branch. The introductory material provides an overview of the various programs supported by the Branch and is followed by a summary of selected recent water quality results and trends. Lake Erie was the focus of 1998/99 ambient monitoring in the Great Lakes, and consequently this Annual Report highlights results from Lake Erie tributary and nearshore monitoring. Subsequent Annual Reports will focus on different Lake Basins according to the lake-by-lake monitoring cycle described in this document.*

The initial overview is intended to provide program managers within the Ministry, as well as other Provincial and Federal agencies, with basic information concerning the current surface water monitoring database and mandate of the Branch. The summary of selected data is provided to illustrate the range of information available to anyone interested in water quality issues. The intention is to allow interested readers to pursue details pertaining to their particular area of interest, whether they represent provincial, federal, or municipal agencies, universities, or consultants. By making this summary widely available we are also endeavouring to improve access to technical information and staff within the Branch. Given the wide range of environmental issues and challenges in the Great Lakes Basin, such access is essential for internal and external program coordination, and the provision of timely and effective client services.

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1.0 Surface Water Monitoring Program Summary

As described in the MOE Business Plan, the provincial commitment to Environmental Protection includes "cleaner air, water, and land, and healthier ecosystems" as Core Business goals. The Ministry's surface water quality management goals associated with this Core Business are to ensure that (a) the quality of surface water is protected to ensure a healthy aquatic ecosystem; and (b) drinking water supplies are safe and aesthetically pleasing. Surface water quality management in Ontario is guided by a range of policies which outline the manner in which the Ministry will apply and enforce the appropriate aspects of environmental legislation (including the Environmental Protection Act, Ontario Water Resources Act, and the Environmental Assessment Act). As described in Water Management Policies, Guidelines and Provincial Water Quality Objectives of the Ministry of the Environment (1994) three of these policies are directly applicable to water quality monitoring:

Policy 1:
In areas which have water quality better than Provincial Water Quality Objectives (PWQOs), water quality shall be maintained at or above the Objectives;

Policy 2:
Water Quality which presently does not meet the PWQOs will not be degraded further and all practical measures will be taken to upgrade the water quality to the Objectives; and

Policy 5:
Mixing zones [areas contiguous to a pollution source where the water quality fails to comply with one or more of the PWQOs] should be as small as possible and not interfere with beneficial uses. Mixing zones are not to be used as an alternative to reasonable and practical treatment.

These Policies require an understanding of the prevailing water quality status as the basis for regulatory decisions (e.g. issuance of a Certificate of Approval). In addition to these policies, the Ministry publication *Deriving Receiving-Water Based, Point-Source Effluent Requirements for Ontario Waters* stresses the importance of background physical, chemical, and biological conditions in developing receiving-water based effluent requirements.

The current surface water ambient monitoring program administered by the Environmental Monitoring and Reporting Branch (EMRB) includes three general components: River Systems Monitoring and Assessment, Great Lakes Nearshore Monitoring and Assessment, and Inland Lake Monitoring (which is undertaken in partnership with Cottagers Associations through the Lake Partner Program and is reported separately).

1.1 River Systems Monitoring and Assessment

The River Systems Monitoring and Assessment Program provides measurement and assessment of water quality and streamflow in tributaries throughout Ontario. Water quality and flow information is used to track long term (>20 years) and recent trends, to map spatial patterns across watersheds with differing attributes, and for the environmental planning and approvals process.

The core program includes the following:

1.1.1 Provincial Water Quality Monitoring Network (PWQMN)
Water quality sample collections are currently undertaken across the province in approximately 50 watersheds in partnership with MOE Regional Technical Assessment Units and Conservation Authorities. Samples are currently collected at approximately monthly intervals from April through November and are analysed for a range of water quality indicators (including temperature, pH, conductivity, turbidity, suspended solids, major ions, nutrients, and metals) in order to screen overall water quality and identify potentially anomalous results.

1.1.2 Enhanced Tributary Monitoring Program (ETMP)
Since 1980 samples have been collected near the mouths of 16 strategically chosen watersheds throughout the Great Lakes Basin representing approximately 50% of the total flow into the Great Lakes from Canadian watersheds. The program tracks long term changes in water quality and contaminant loadings. Currently, approximately 20 samples per year are collected at each station with an emphasis on the spring freshet which typically accounts for a significant proportion of annual contaminant loadings. Samples are analysed for the same parameters as the PWQMN samples with additional analysis for trace organics (e.g. PCBs and organochlorine pesticides, and other in-use pesticides at selected locations). Results from this program provide a means of assessing spatial and temporal trends in water quality and contaminant loadings among and within major watersheds, and allow the screening of potential "problem" watersheds. This activity also supports the Provincial commitment to the Great Lakes Water QualityAgreement (GLWQA)of the International Joint Commission (IJC).

1.1.3 Streamflow Network
Hydrometric data are fundamental to the information required by MOE for water quality assessments, pollutant loading computations, discharge approvals, issuing of *Permits to Take Water*, resolution of interference complaints, and policy and standards development. Presently there are about 325 stations in the Ontario network. A 1975 Agreement between Canada and Ontario regarding hydrometric surveys in the province includes MOE as a signatory. Environment Canada acts on behalf of the federal government as both a partner and operator of the network while the Ministry of Natural Resources is the major partner acting on behalf of the province of Ontario. The purpose of the agreement is to provide a coordinated, standardized and cost-shared approach to the collection of streamflow data. Under the terms of the Agreement, the provision of partial annual funding for the operation and maintenance of the network gives MOE access to all collected hydrometric data.

1.2 Great Lakes Nearshore Monitoring and Assessment Program

This program is designed to measure environmental indicators related to toxics, nutrients, micro-organisms, and exotic species in the nearshore areas of the Great Lakes and connecting channels. It also provides assessments of site-specific environmental problems, and effectiveness of remedial and abatement activity in nearshore areas, harbours and embayments (including "Areas of Concern" identified by the International Joint Commission). In addition to meeting internal MOE information requirements, this program also supports the Provincial commitment to the Great Lakes Water Quality Agreement of the International Joint Commission (as described through the Canada-Ontario Agreement Respecting the Great Lakes Basin Ecosystem).

Core elements of ambient monitoring are undertaken on a lake-by-lake basis over a multi-year cycle to provide good spatial coverage of the Great Lakes while maintaining an acceptable level of sampling frequency for most data uses. A periodic sampling cycle, that allows for a greater intensity of sampling in Lakes Ontario and Erie (the lake basins under greatest stress), is guiding the field schedule for most of the program elements. The current planned cycle is as follows:

Year	Lake Basin/Connecting Channels
1998	Lake Erie, Detroit River, Lake St. Clair, St. Clair River
1999	Lake Superior, St. Mary's River, North Channel
2000	Lake Ontario, St. Lawrence River, Niagara River
2001	Lake Erie, Detroit River, Lake St. Clair, St. Clair River
2002	Lake Huron, Georgian Bay
2003	Lake Ontario, St. Lawrence River, Niagara River

The core nearshore monitoring and assessment program includes the following elements.

1.2.1 Great Lakes Index Station Monitoring

"Index" and "reference" stations are located in areas representative of background conditions and in areas where there is a natural integration of the stressors from a larger area. Fifty-seven core sites (Figure 1.2.1) have been established throughout the Great Lakes basin and a minimum of seven sites are visited within a lake basin each year according to the lake-by-lake cycle. This network of stations is designed to provide information on where and how water quality conditions are changing over time by periodically monitoring a suite of environmental indicators. Sampling is undertaken for summer concentrations of priority toxic contaminants in sediment and suspended particulate material as an indicator of the level of priority contaminants present in the aquatic environment. Summer species composition and abundance of benthic invertebrates are monitored as a biological indicator of overall ecosystem health and as a general stress response indicator. Spring, summer, and fall sampling is undertaken for various physical measurements including thermal and optical profiles of the water column, and physical characterization of the lake bottom as indicators of habitat integrity.

1.2.2 Great Lakes Reconnaissance Monitoring

Reconnaissance monitoring is designed to identify the status of environmental indicators in the immediate nearshore zone most strongly and directly affected by land-based activities and is undertaken in two parts. The first involves "real-time" mapping and sampling of nutrient, bacteriological, physical and aesthetic features of water quality along selected ranges of shoreline. The second, Harbour Sediment Quality Screening, involves more extensive sampling at a limited number of key sites (frequently within the above survey areas) where water quality conditions at sites are known to be impacted or have a potential for impact. Sampling for trace contaminants

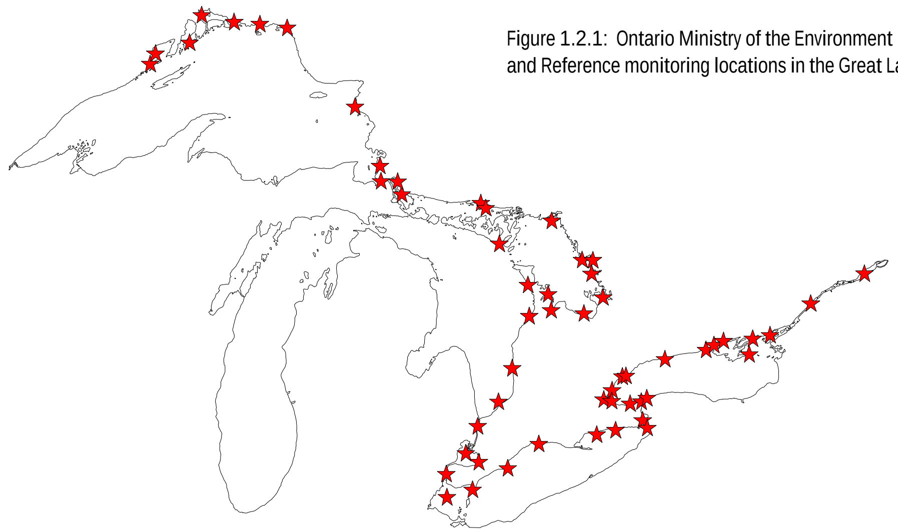

Figure 1.2.1: Ontario Ministry of the Environment Index and Reference monitoring locations in the Great Lakes.

and sediment quality is conducted at these stations to enable calculation of various water and sediment quality indices. Water quality mapping and sediment screening data are compared with Provincial Water Quality Objectives (PWQOs) and Provincial Sediment Quality Guidelines (PSQGs) to screen harbours and embayments (including those which have not been the traditional focus of attention by the IJC) for sources of pollutants such as municipal and industrial effluent discharges, and historical accumulations in sediment.

1.2.3 Great Lakes Toxics Biomonitoring

Long-term monitoring of contaminant levels in mussels, zebra mussels, juvenile fish, and selected sport fish is undertaken to track levels of toxic contaminants (i.e. persistent, bioaccumulative substances) through time across the Great Lakes. Sportfish results reflect the long-term, spatially integrated effects of exposure to persistent bioaccumulative substances (e.g. PCBs, dioxins/furans) and provide a superior means of tracking long-term trends over the basin as a whole. They also form the basis of the *Guide to Eating Ontario Sportfish*. Mussel and juvenile fish data, on the other hand, provide a localized, short-term means of identifying problem zones and potential contaminant sources.

1.2.4 Great Lakes Tributary Toxics Monitoring

This screening-level sampling is intended to identify those tributaries that may have locally controllable sources of persistent bioaccumulative substances to each of the Great Lakes on an annual lake-by-lake cycle. A combination of biomonitoring, flow monitoring, and temporally integrated large-volume sampling for trace organics (PCB congeners, organochlorines, chlorobenzenes, PAHs), physical parameters, nutrients, and metals is employed.

1.2.5 Great Lakes Water Intake Monitoring

Water intake monitoring is undertaken to identify long term trends in nutrient status using year-round (weekly-monthly) nutrient concentrations and phytoplankton biomass as indicators. Monitoring has been ongoing for more than 20 years from raw intake water at 18 water treatment plants that draw water from the Great Lakes. Six of these are situated in Lake Erie. Results are used to assess the effectiveness of nutrient management programs in the Great Lakes. A secondary benefit of this monitoring data is that it may provide an indication of effects from a variety of stressors not actively monitored in the aquatic environment (e.g. effects of UV radiation and climate change) since shifts in algal composition beyond the normal range of previous patterns of variability provide a general indicator of environmental change.

1.3 Investigations and External Services

There remains an ongoing need for a number of investigative surveys designed to assess the nature and extent of site-specific environmental impacts from known contaminant sources. These investigative surveys are frequently undertaken as part of the regulatory and enforcement mandate of MOE Operations Division, or as part of the federal-provincial Remedial Action Plan program that address the restoration of Ontario's sixteen Great Lakes Areas of Concern. Investigative surveys include a review of environmental conditions to assess compliance with PWQO's and guidelines and results can be used to evaluate the effectiveness of cleanup efforts. These types of investigations are integrated with the core ambient monitoring survey schedule and results are reported in Technical Memoranda or more detailed reports to the client.

2.0 Selected Results and Trends for Lake Erie Tributary and Nearshore Water Quality Monitoring

2.1 Summary Description of the Lake Erie Basin

Lake Erie is the smallest of the Great Lakes (483 km^3) by volume and next to the smallest in surface area (25 700 km^2). The lake is naturally divided into three basins. The western basin is shallow (mean depth = 7 m), fully mixed, and is separated from the central basin by a ridge running southeast from Point Pelee. The central basin (mean depth = 19 m) stratifies in summer when areas of bottom water can exhibit low oxygen conditions. The eastern basin is the deepest portion of the lake (mean depth of 25 m; maximum depth 64 m) and is separated from the central basin by a ridge running south from Long Point. Gradients in temperature and trophic status exist along the east-west axis of the lake, with the western basin exhibiting the warmest temperatures and relatively higher concentrations of nutrients and algae.

Approximately 80% of the water flowing into Lake Erie comes from the upper Great Lakes (Superior, Michigan, Huron) through the St. Clair River, Lake St. Clair and the Detroit River. The remaining 20% is contributed by precipitation and tributaries in Michigan, Ohio, Pennsylvania, New York and Ontario. The Niagara River and shipping canals, such as the Welland Canal, serve as Lake Erie's outlets and drain into Lake Ontario. As the shallowest of the Great Lakes the retention time of water in Lake Erie is about 2.6 years.

The Lake Erie basin (including the St. Clair River, Lake St. Clair, and the Detroit River) has an area of 78 000 km^2. As a percentage of total land use, agricultural and urban land uses within the Lake Erie watershed are the highest in the Great Lakes basin. Most of land area is used for agriculture (approximately 60%) though there has been considerable growth and expansion of urban areas along major tributaries on the Canadian side. About a third (approximately 12 million people) of the total population of the Great Lakes basin reside within the Lake Erie basin. A majority of these inhabitants depend on Lake Erie for drinking water.

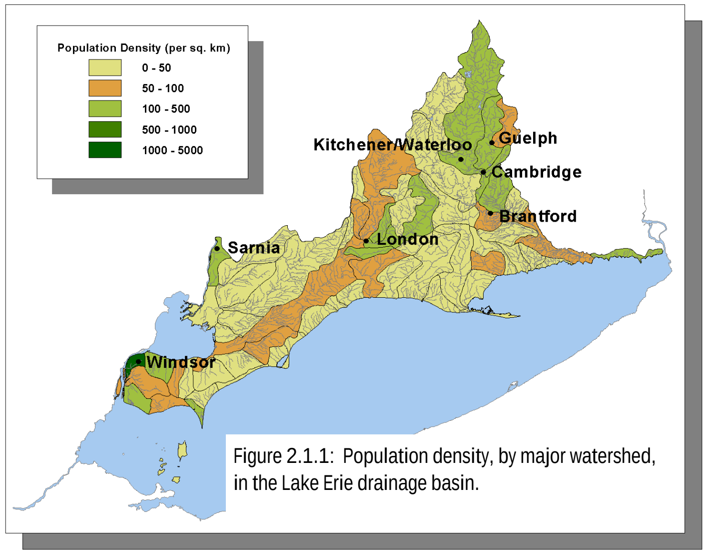

Figure 2.1.1: Population density, by major watershed, in the Lake Erie drainage basin.

Lake Erie is the warmest and most biologically productive of the Great Lakes. The lake supports a long-term commercial fishery catch of > 10 million kg/yr in Canadian waters and a valuable sports fishery for walleye and yellow perch. During the 1960s, Lake Erie gained a reputation in the media as a 'dead lake' due to extensive zones of oxygen depleted bottom waters. This condition was linked to the overproduction of phytoplankton in response to the excessive loading of the nutrient phosphorus from municipal sewage and agricultural runoff. Since the 1960s, significant reductions in phosphorus loading have been achieved, however, phosphorus remains a concern in Lake Erie. With the establishment of exotic species in the lake there is uncertainty regarding the routing of nutrients in the food web, and in particular the role that zebra mussels are playing in altering the phosphorus balance.

2.2 Land Use, Pollution Sources, and Selection of Water and Sediment Quality Indicators

2.2.1 Land Use and Pollution Sources

The extensive rural/agricultural and urban/industrial land use activity within the Lake Erie basin accounts for a range of pollutants entering tributaries and lakes from "point sources" (e.g. industrial and municipal effluent discharges) and "non-point sources" (e.g. diffuse runoff from urban or agricultural areas). These pollutants include suspended solids, dissolved solids, bacteria, nutrients, metals, and trace organic contaminants (including pesticides, PCBs, and a range of industrial organic chemical by-products). Associated impacts can range from short-term restrictions on recreational water use, to impaired aquatic and benthic habitat, to uptake and magnification of persistent trace organics through the food web resulting in potential harm to fish eating birds and mammals (including humans). Identifying the location and extent of possible impacts remains a key challenge in the design of an effective monitoring program.

Contaminants associated with urban runoff include polycyclic aromatic hydrocarbons (PAHs), metals and petroleum hydrocarbons associated with vehicle exhaust, brake and tire wear, fuel and engine oil leaks or spills, and corrosion. Other contaminants associated with urban runoff include suspended solids, nutrients, pesticides and bacteria from sanitary sewer cross connections, infiltration from the sanitary sewer system, accidental or deliberate spills to road side catch basins, chemical applications (fertilizers and pesticides) runoff from commercial/industrial storage areas, and faecal material from wildlife and domestic animals.

Pollutants linked to rural and agricultural land uses can overlap to some degree with urban sources and include suspended solids, nutrients and bacteria from fertilizer and pesticide crop applications, runoff from animal storage areas; and faecal material from livestock. The relative impact of suspended solids, fertilizers and pesticides on rural streams can vary widely with the season and local farm practices but can be significant, particularly during the spring.

Not all pollutants are locally or recently generated. Many of the persistent "trace organic compounds" which can still be detected in the water, sediment, and biota of Lake Erie and its tributaries are pesticides which have not been used in Ontario for decades (if ever) and which may be partially attributable to long-range atmospheric transport from other parts of the globe. Spatial and temporal trends in water quality throughout this area of the province can often be attributed to shifts in land use patterns, as well as reductions in contaminant loads from wastewater discharges, over the past 20 years.

2.2.2 Selection of Water Quality Indicators

Effective water quality monitoring requires more than the collection and analysis of water samples. Many persistent contaminants of concern are hydophobic (i.e. they have low solubility in water) and tend to bind to sediment particles or become incorporated into fatty tissue in animals. The life cycle of many of these contaminants includes a potentially protracted association with lake bottom sediments, as well as transmission through the food web. Sediment sampling provides a means of tracking the legacy of historical contaminant loadings, and biological tissue analysis provides a means of assessing biological exposure to persistent, bioaccumulative substances. Assessment of other biological indicators (such as the identification and enumeration of benthic invertebrate species) also provides a means of linking chemical contamination of water and sediment with an impact on the biological community.

Surface water sampling is undertaken for a wide range of water quality, sediment quality, and biomonitoring parameters (samples are analysed for >150 chemicals, depending upon the specific objec-

Program Activity
Stream Water Quality
Lake Erie Tributary Toxics
Lake Erie Nearshore Index Station Monitoring and Intake Monitoring for water quality
Lake Erie Nearshore Index Station and Lake Erie Reconnaissance Monitoring for sediment quality

tives associated with program sub-projects). A subset of general indicators which illustrate the relationships between land use and pollution, and the subsequent potential impact on the aquatic environment, are presented here. Additional, detailed information is available in MOE publications and scientific papers which are produced as part of the monitoring program.

2.2.3 Chloride

Chloride is a naturally occurring ion associated with dissolved salts; the most common of these being rock salt (sodium chloride) and is an example of a conservative water quality pollutant. Rock salt is the most commonly used de-icing salt used in southern Ontario and is the largest single source of chlorides entering Lake Erie from Ontario sources. Typical chloride concentrations found in the basin are well below any guidelines for protection of domestic water supplies, industrial water supplies, irrigation, or fish and aquatic life. Regardless of its potential as a harmful substance, chloride can be used as a tracer for other pollutants associated with runoff from roads and urban areas.

2.2.4 Suspended Solids

As with chloride, typical concentrations of suspended solids, throughout much of the year, do not necessarily cause any direct stress to aquatic life or impose undue restrictions on beneficial water uses such as recreation. However; concentrations throughout the year tend to vary widely due to the link between flow and suspended solids concentrations in tributaries and at tributary mouths. These potentially extreme fluctuations can exert considerable stress on aquatic life, particularly in tributaries where the potential to avoid the affected area is limited and during critical periods such as spawning migrations. Apart from its potential to cause direct harm, suspended solids are a good complementary indicator to chloride in that they are a good tracer of contaminants such as metals and trace organics which have low solubility in water and tend to bind preferentially with suspended solids (including inorganic material like silt and clay, and particulate organic matter such as algae). In many cases this tendency results in these types of contaminants being found at extremely low concentrations in water except in areas with high suspended solids.

2.2.5 Nutrients (Phosphorus and Nitrate)

Phosphorus is an essential nutrient for plant and animal growth. Total phosphorus is a measure of all dissolved and particulate forms of phosphorus and in southern Ontario is generally the nutrient responsible for “cultural” eutrophication (i.e. the unnatural enhancement of algal productivity and the resulting enrichment of organic matter and depletion of oxygen) that can threaten aquatic habitat and impair the aesthetic value of lakes and streams.

Phosphorus enrichment is often linked to agricultural

runoff from poorly protected soil containing fertilizer, or directly from faeces in situations where access to tributaries is provided for livestock watering. It can also result from faulty septic system operations in rural areas. Enrichment can also occur in urbanized watersheds as the result of sewage treatment plant (STP) discharges, combined sewer overflows following heavy rain (containing untreated sanitary sewage), and storm sewers channelling runoff containing animal faeces and fertilizer from lawns. Although excess phosphorus loading to Lake Erie is not a new issue, and improvements at point sources such as STPs have been effective, contributions from the diffuse sources mentioned above often produce concentrations in tributaries and at tributary mouths that exceed the interim Provincial Water Quality Objective (PWQO) for avoidance of nuisance concentrations of algae. Due to the link between agricultural and residential application of fertilizers and pest and/or weed control chemicals total phosphorus can be used as a tracer of "in use" pesticides and herbicides.

Nitrate is a naturally occurring form of nitrogen found in soil and is another essential nutrient for plant growth (although it is seldom the limiting nutrient linked to eutrophication in the Great Lakes Basin). It is also highly soluble and can leach into tributaries and groundwater. Although there may be health effects associated with high nitrate levels in water, typical concentrations found in the Lake Erie basin are well below Ontario Drinking Water Objectives, and are far below any concentrations documented to have resulted in impairment of livestock water supplies. The detection of increased concentrations in the vicinity of STP discharges is usually evidence of ammonia nitrification which consumes oxygen and can result in harmful oxygen depletion if it occurs in the receiving water body rather than the treatment plant.

Nitrate enrichment patterns associated with urban and rural land use practices are generally similar to phosphorus (i.e. nitrate precursors are also a significant component of fertilizer and animal waste). This pattern is complicated by naturally occurring nitrogen fixation from the atmosphere (chiefly by soil bacteria and legumes) and the complex nitrogen cycle. Consequently its use as a tracer of human activity and pollution is less direct than phosphorus. It is worth noting that its limited role in cultural eutrophication (and hence oxygen depletion and production of nuisance algae) has meant that it has not been targeted for loading reductions throughout the Great Lakes basin.

2.2.6 Trace Organics (total PCBs, total DDT, and total PAHs)

Polychlorinated biphenyls (PCBs) are ubiquitous in the environment and can be detected globally in sparsely populated, non-industrialized environments such as the Canadian arctic. This widespread pattern of detection stems from historical uses in electrical equipment (transformers, capacitors), heat exchangers, plasticizers, hydraulic fluids, inks, adhesives, and flame retardants prior to 1971. Although the manufacture of PCBs stopped in the late 1970s, there are still large quantities in use in closed electrical systems as well as accumulations in historical landfill sites. Local influences are observable in water, sediment, and tissue concentrations in addition to the general effect of global recycling through long range atmospheric transport and deposition.

Use of the insecticide DDT in North America started in the 1940s and peaked in the 1960s. DDT was phased out in the 1970s following the discovery of its persistence and tendency to biomagnify through the food web. In some parts of the world it is still used on a large scale as a means of controlling malaria. DDT is metabolized in living organisms into DDD and DDE and, since the sale and use of DDT has been eliminated in Ontario, it is unusual to detect DDT itself in water, sediment, or biota. The most commonly detected form is now DDE which is the most persistent and most toxic metabolite. Relative to PCBs, total DDT is less frequently detected in tributaries at concentrations exceeding its PWQO (3.0 ng/L). Sediment and tissue data also suggest that current levels of DDT in Ontario have responded in a satisfactory manner to the policy of use restric-

tions and phasing out.

Polycyclic aromatic hydrocarbons (PAHs) represent a category of persistent organic pollutants that arise as by-products of manufacturing and combustion, hence their typical association with vehicle exhaust and steel-making operations that employ coking ovens. They are also produced through combustion of wood (including forest fires) and consequently differ from PCBs in that they are not synthetic chemicals produced strictly through human activity. The existence of low level background concentrations of PAHs in the environment; however, does not obscure their use as a tracer of urban and industrial activity, given that they are a major constituent of crude oil and creosote (which is derived from coal tar). They also differ from chlorinated substances such as PCBs in that most living organisms can metabolize them and hence they do not biomagnify through the food web. They are persistent and, in some cases, can bioaccumulate causing harm during metabolism. Certain PAHs have been linked to cancer and genetic damage.

PCBs, DDT, and PAHs are examples of those contaminants of concern that are relatively insoluble in water and tend to be adsorbed to suspended sediment and organic matter in the water column. As a result, analysis of water samples for trace organic contaminants has been hampered by their extremely low concentration in ambient water relative to analytical detection limits (except in extremely turbid water). When the particulate material settles out, these contaminants are transported into the bed sediment where they can enter the benthic food web, or be reintroduced into the water column by physical resuspension or chemical desorption. Due to the tendency for these contaminants to preferentially bind to sediment it is more effective to monitor sediment and biological tissue chemistry, rather than water, in order to observe the effects of contaminant sources or as a means of tracking the effectiveness of remedial actions.

2.2.7 Metals (Copper, Lead, Mercury, and Zinc)

Unlike many of the trace contaminants previously discussed, metals are naturally occurring elements found in the earth's crust. They are also good tracers of a wide range of industrial activity and urbanization. Copper, lead, mercury and zinc have been selected as indicators of "metal pollution".

Certain forms of copper are relatively soluble compared with other metals and copper tends to be the most commonly detected metal in the surface waters of southern Ontario. It's use in piping is well known and is a direct source of enrichment in urban settings since most household waste water will have travelled through copper pipe as part of the supply system. It is also widely used in metal alloys, wiring, and in insecticides and fungicides and can be a tracer of a wide range of urban and rural land use practices. It is not found in Ontario at sufficiently elevated concentrations to represent a human health concern.

The use of lead as a fuel additive (until it was phased out during the 1980s) in paint, as solder, and as shot accounts for the ubiquitous nature of lead enrichment in urban soil and sediment, and water. Lead has been linked to animal human health effects as a cumulative general poison with pregnant women, fetuses, and infants at the greatest risk.

Mercury is a trace element that exists in the environment in a variety of organic and inorganic forms. It was used in many industrial applications including chloralkali industry, paint, agriculture, dentistry, and pulp and paper production. In the late 1960s and early 1970s, government and industry took action to reduce its use and direct discharges of mercury from industrial sources were significantly reduced. Due to its relative insolubility in water, mercury preferentially binds to particulate matter and is easily transported from the water column to bed sediments. Mercury deposited in sediment can be converted by microorganisms to methyl-mercury derivatives. These derivatives can then become concentrated along a food chain with toxic effects on biota, including humans.

Although zinc is an essential element for plant and animal nutrition, its use in metal galvanizing and plating, as well as in dyes and paints can be linked to enriched concentrations in urban and industrial watersheds, along with enrichment of sediment in Lake Erie harbours. Like copper, it is not found in Ontario at sufficiently elevated concentrations to represent a human health concern.

Many metals are also relatively insoluble in water and, like trace organic substances, tend to be associated with suspended sediment and organic matter in the water column. Due to this tendency, it is often more effective to monitor sediment and biological tissue chemistry, rather than water, in order to observe the effects of contaminant sources or as a means of tracking the effectiveness of remedial actions.

2.3 Lake Erie River Systems Monitoring

To investigate trends in tributary water quality, median concentrations were calculated for selected water quality parameters at all of the Provincial Water Quality Monitoring Network (PWQMN) Stations within the Lake Erie drainage basin. Sample results were pooled at each station for the period extending 1997-1999 (typically > 20 samples). Additional data were pooled for the period 1993-1995 and included in the mapping to supplement the spatial coverage.

The long period of record available at many PWQMN stations permits the investigation of temporal trends in water quality. In this report, long-term trends have been examined by comparing data collected from 1980-1982 to data collected at corresponding stations from 1993-1995 or 1997-1999. An examination of the variation about the median for each of the time periods was used to determine the significance of long-term changes in concentration for selected parameters.

Examination of the PWQMN data reveals that Lake Erie tributaries are enriched with the nutrient phosphorus. The plotted results for total phosphorus concentration demonstrate that a large proportion (87%) of the stations have a median total phosphorus concentration that exceeds the interim Provincial Water Quality Objective (PWQO) of 30 μg/L to avoid the nuisance growth of algae. The long-term trends observed at PWQMN stations in the Lake Erie drainage basin reflect phosphorus load reductions, primarily through improved treatment at point source discharges such as sewage treatment plants but also through improved agricultural practices. Thirty-eight percent of the stations demonstrate a significant reduction in total phosphorus concentration, 61 percent show no change, while less than one percent show a significant increase despite the increase in population growth over the period of comparison. The trend suggests that phosphorus control efforts have been effective, but the routine detection of total phosphorus concentration above the PWQO at most stations suggests that further action is required in controlling phosphorus sources.

Median nitrate concentrations range from 10 μg/L to 970 μg/L at Lake Erie tributary stations. Nitrate concentrations in tributaries have changed little since the early 1980s owing primarily to the fact that nitrogen has not been targeted for point source load reductions. Eight percent of PWQMN stations exhibit an increasing trend, six percent have a decreasing trend,

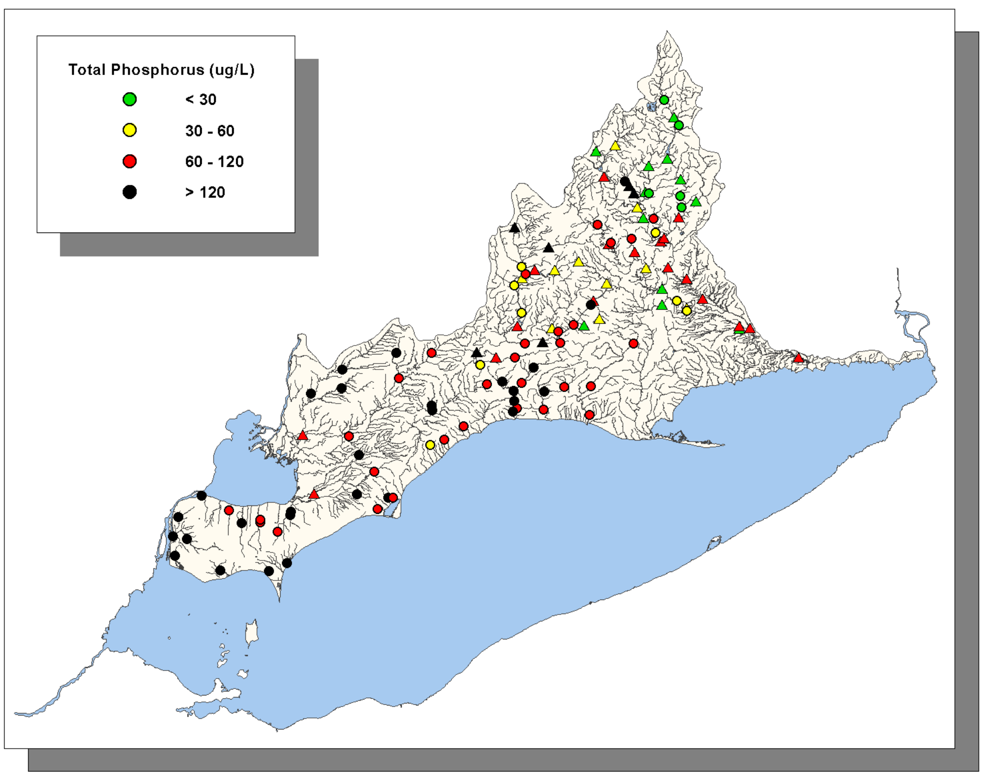

Figure 2.3.1: Median total phosphorus concentration at Lake Erie watershed (PWQMN) stations (1993-1995 circles; 1997-1999 triangles).

while 86 percent indicate no significant change in nitrate concentration.

Contrary to the total phosphorus trend, chloride concentrations have increased significantly over the last two decades. Eighty-eight percent of the PWQMN stations monitored in the Lake Erie basin exhibit a significant increase in chloride concentration, five percent demonstrate no change and seven percent have decreased. The high percentage of stations with an increasing chloride trend is indicative of the significant amount of urbanization and development that has occurred in watersheds in southern Ontario since the early 1980s. Although currently observed chloride concentrations do not pose a significant threat to aquatic biota, increasing chloride concentrations may be indicative of an increasing trend in other pollutants such as PAHs.

Median suspended solids concentrations range from 3 mg/L to 92 mg/L at Lake Erie tributary stations. Spatial patterns in suspended solids concentrations reflect variations in surficial geology and land use, with the upper portions of the Grand and Thames River watersheds exhibiting the lowest concentrations of suspended solids in the Lake Erie basin. Suspended solids concentra-

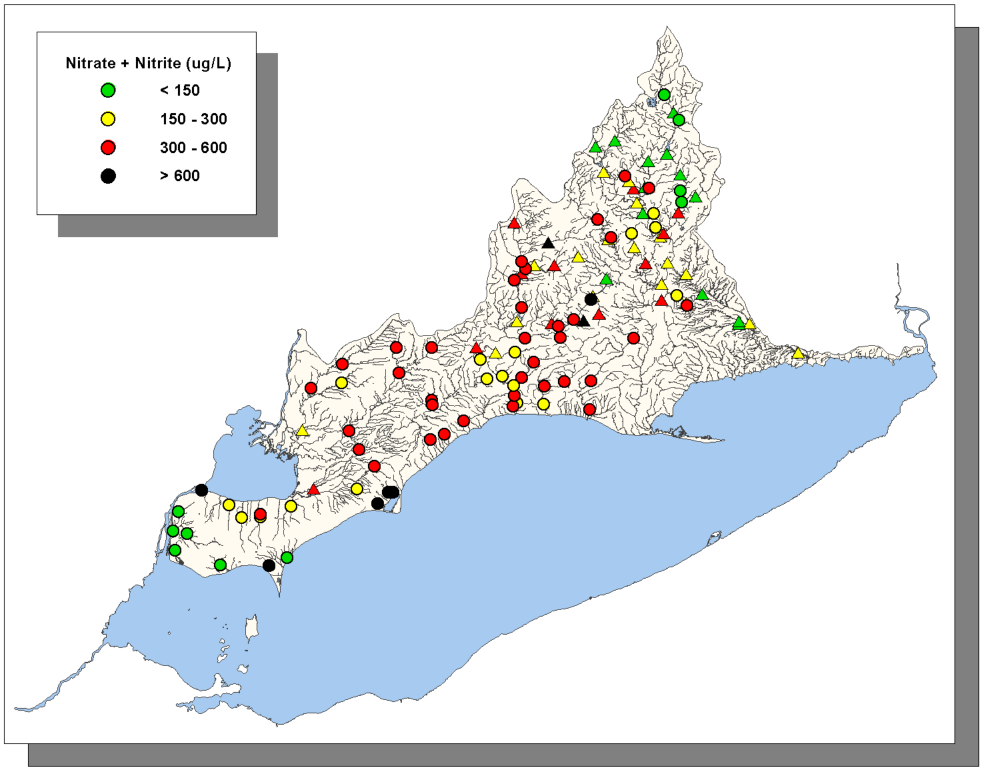

Figure 2.3.2: Median nitrate concentration at Lake Erie watershed (PWQMN) stations (1993-1995 circles; 1997-1999 triangles).

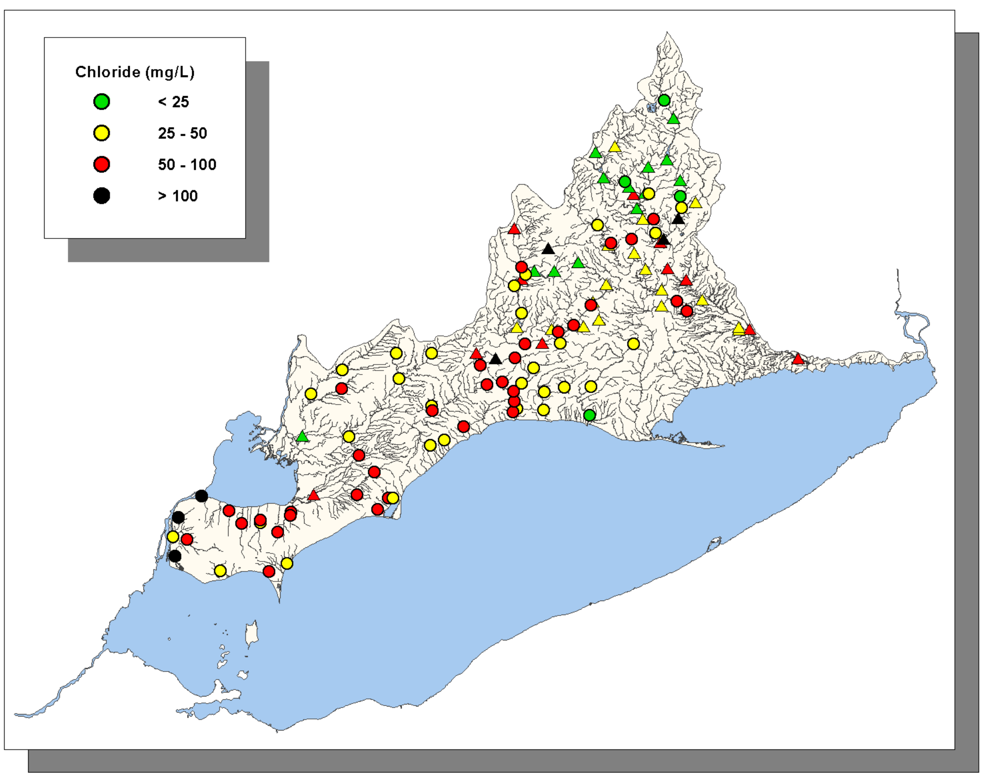

Figure 2.3.3: Median chloride concentration at Lake Erie watershed (PWQMN) stations (1993-1995 circles; 1997-1999 triangles).

tions have not changed significantly at most stations. Seven percent of PWQMN stations exhibit an increasing trend, thirteen percent have a decreasing trend, while 80 percent indicate no significant change in suspended solids concentration.

Inter-station comparisons of median concentrations for selected parameters can generate meaningful results if the sample distribution is representative of the range of hydrologic conditions. It is prudent to note that bias is introduced to the median statistic through the selection of sampling dates. Variable frequency runoff events from rain and snow-melt can significantly affect water quality in tributaries and the associated nearshore zone. Thus, the confidence associated with the median concentration depends largely on the relative proportion of samples collected during low-flow (baseflow) and high-flow (stormflow) conditions. A more robust analysis of time series trends can be achieved by partitioning tributary water quality data by streamflow.

To further investigate temporal trends in tributary water quality, streamflow data were used to calculate load and flow-weighted mean concentration of total phosphorus and chloride at an Enhanced

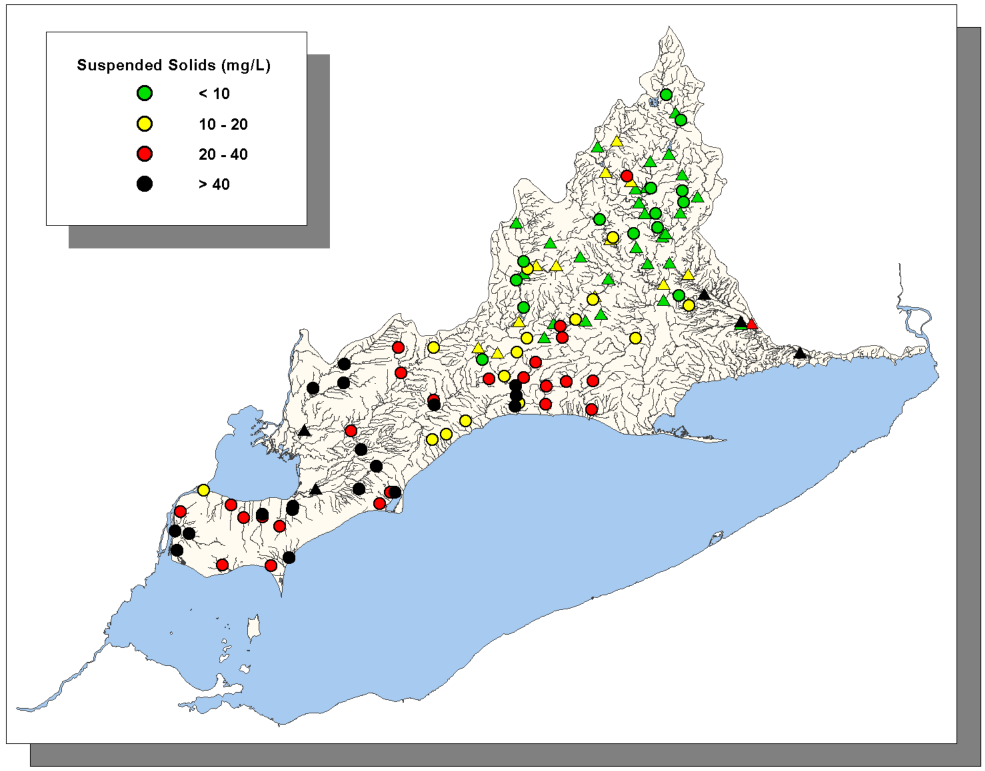

Figure 2.3.4: Median suspended solids concentration at Lake Erie watershed (PWQMN) stations (1993-1995 circles; 1997-1999) triangles).

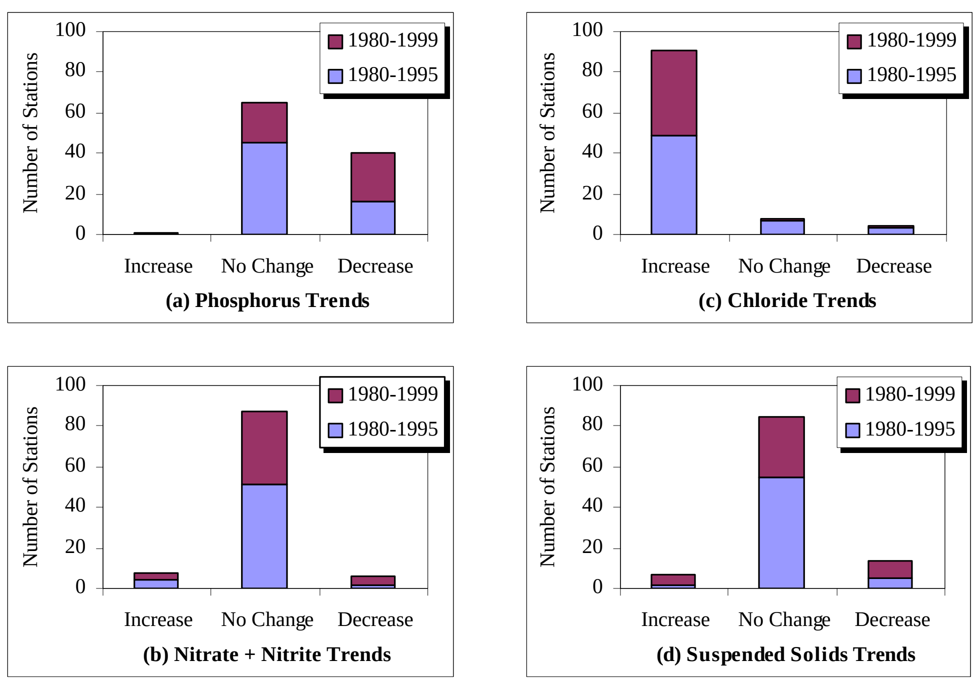

Figure 2.3.5: Long-term trends in (a) total phosphorus, (b) nitrate, (c) chloride and (d) suspended solids concentration at Lake Erie watershed (PWQMN) stations.

Tributary Monitoring Station (ETMP) on the Grand River at Dunnville. The Grand River watershed encompasses almost 30 percent of the total land area of the Lake Erie watershed representing an approximation of trends for the whole of the basin. Long-term trends in flow-weighted concentration and load corroborate the findings of the previously presented analyses. While flow-weighted total phosphorus concentrations continue to exceed the interim PWQO, a declining trend in concentration and load is evident. Conversely, an increasing trend in flow-weighted chloride concentration and load is evident.

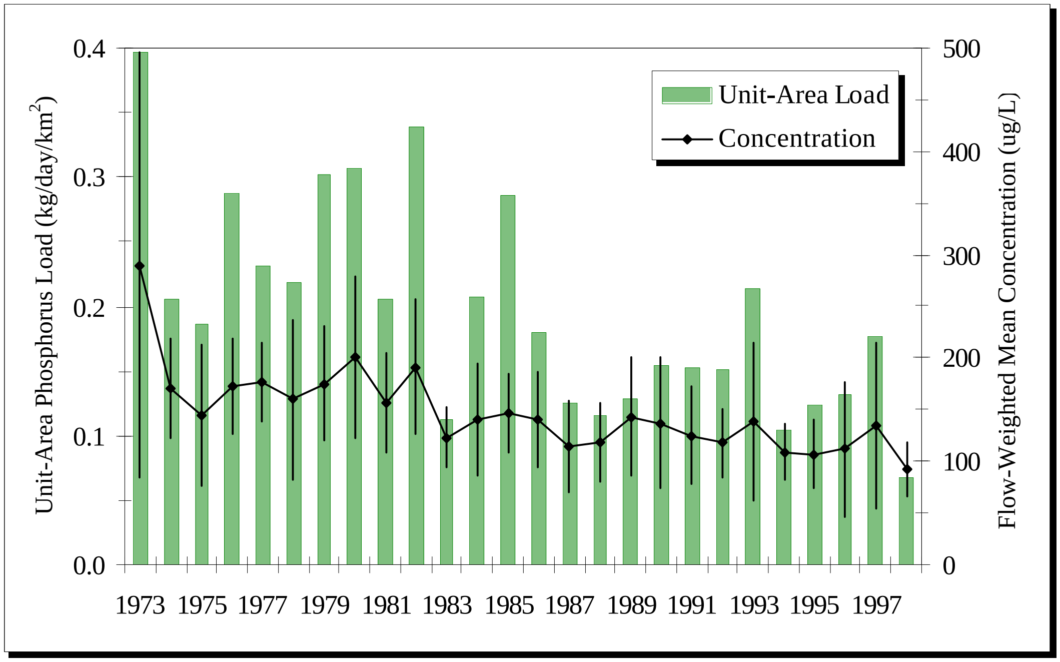

Figure 2.3.6: Annual unit-area load and flow-weighted mean concentration (with 95% confidence intervals) of total phosphorus at an Enhanced Tributary Monitoring Station on the Grand River at Dunnville.

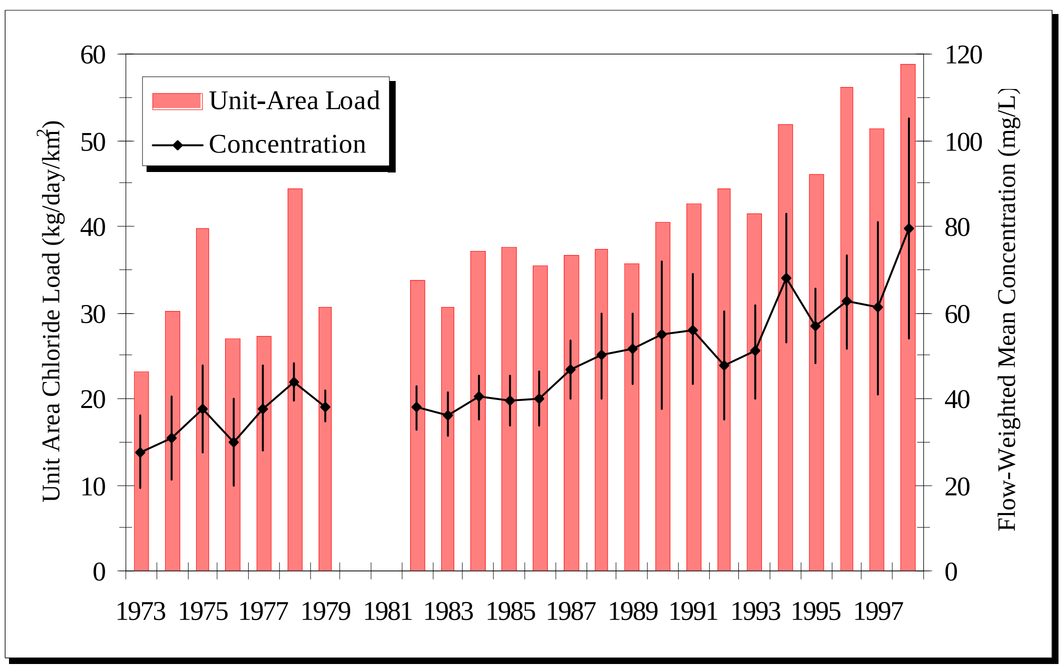

Figure 2.3.7: Annual unit-area load and flow-weighted mean concentration (with 95% confidence intervals) of chloride at an Enhanced Tributary Monitoring Station on the Grand River at Dunnville.

2.4 Lake Erie Tributary Mouth and Nearshore Water Quality Monitoring

Median contaminant concentrations for tributary mouth, and the near-shore zone of Lake Erie are presented to provide a general illustration of surface water quality. As previously noted, wet weather events and runoff play a significant role in determining water quality in tributaries and the nearshore zone despite their variable frequency of occurrence. Since 50% of the samples fall below the median concentration (by definition) it is evident that this value will depend largely upon the proportion of wet weather samples represented in the data. A more sophisticated analysis of tributary and nearshore data can be achieved by partitioning the results according to tributary flow, lake currents, and weather conditions. However, this falls outside the scope of this report.

2.4.1 Tributary Toxics Monitoring

Eight tributaries in the Ontario portion of the Lake Erie watershed were sampled during 1998 and 1999. These tributaries were selected to represent the range of land use and streamflow conditions that exist in the Lake Erie basin. Monitoring was undertaken to identify watersheds (if any) exhibiting evidence of contaminant sources. Improved methods of sample collection (large-volume samples) and analysis (lower detection limits) yielded a limited number of results (9 to 12 samples depending on location) for trace organic contaminants and metals.

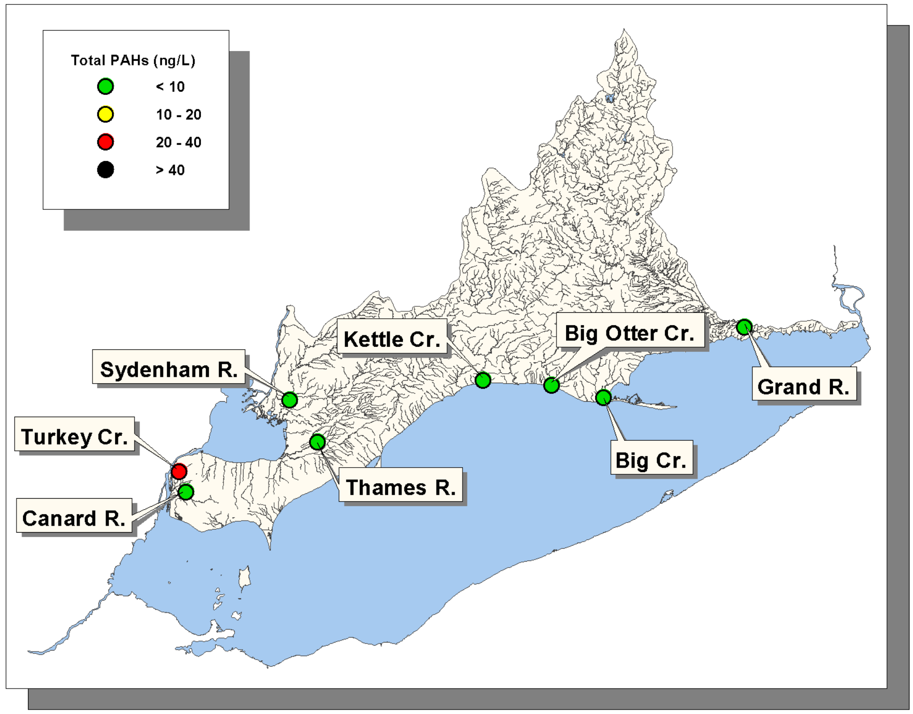

Figure 2.4.1: Median concentration of total PAHs from 1998/99 Tributary Toxics Monitoring.

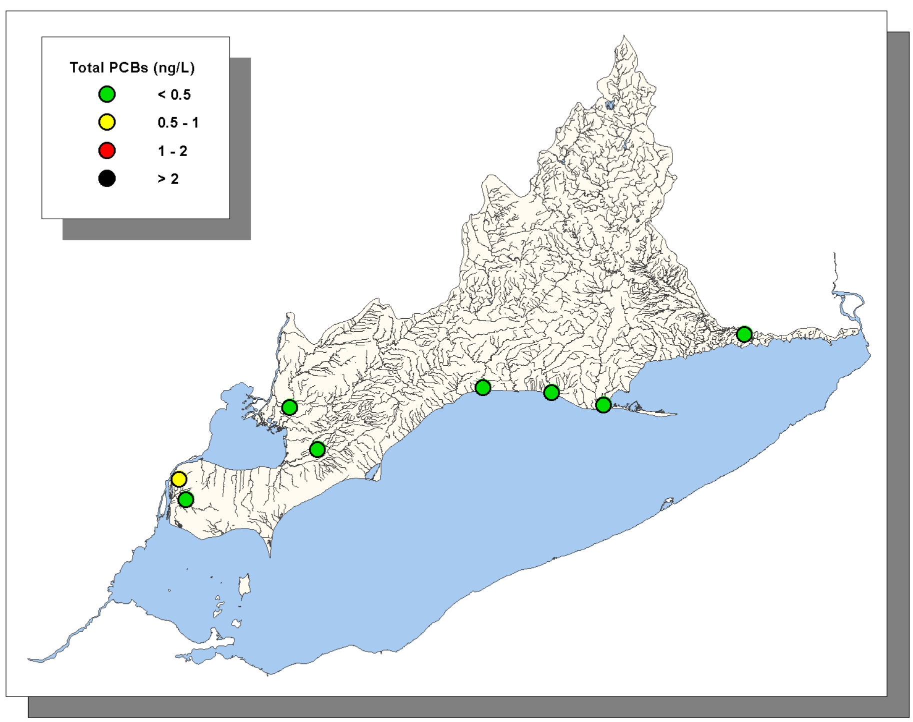

Figure 2.4.2: Median concentration of total PCBs from 1998/99 Tributary Toxics Monitoring.

Although there is no PWQO for total PAHs (interim PWQOs for individual PAHs range from 0.02 ng/L to 7.0 µg/L), the tributary mouth data reflect land use with median concentrations at Turkey Creek exceeding those observed elsewhere around the lake. A similar pattern is evident for total PCBs and copper with median concentrations equal to, or exceeding, their respective PWQOs at Turkey Creek. Elevated concentrations of organic contaminants and metals at Turkey Creek are the result of higher frequencies of detection and are indicative of the industrial and urban land uses in the watershed.

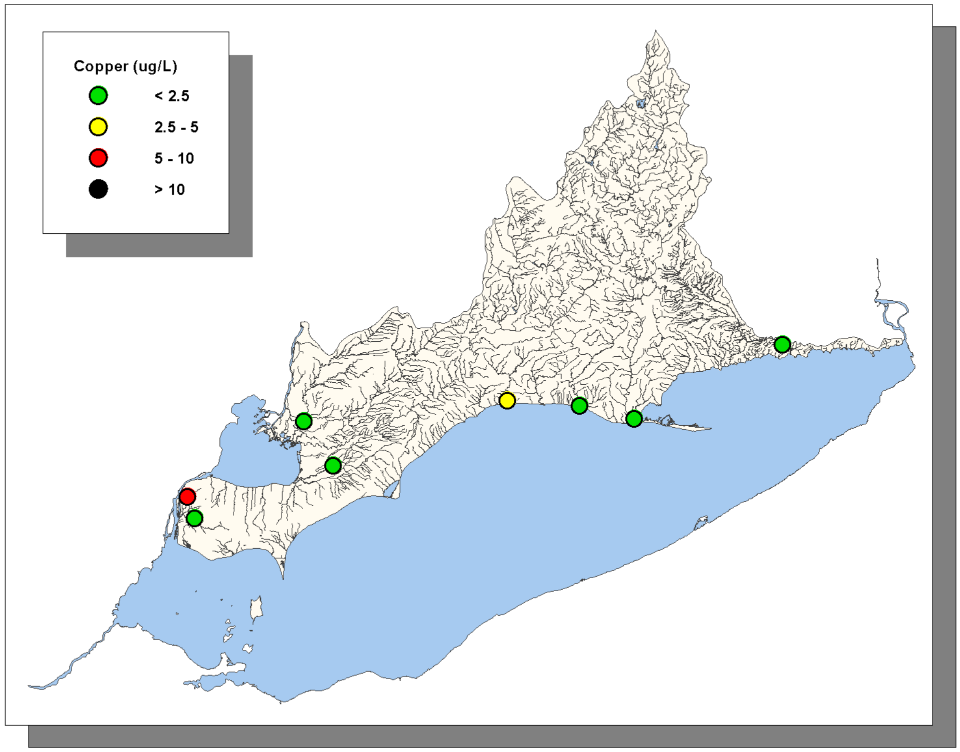

Figure 2.4.3: Median copper concentration from 1998/99 Tributary Toxics monitoring.

2.4.2 Lake Ontario Index Station Monitoring

Median chloride concentrations of less than 25 mg/L are evident at all Lake Erie index stations, despite concentrations exceeding 100 mg/L in some tributaries. Chloride concentrations in the nearshore are influenced predominantly by open-lake ambient conditions that are, in turn, influenced by flows from the upper Great Lakes via the Detroit River. The tendency for nearshore concentrations to reflect open-lake ambient conditions accounts for the relatively uniform chloride concentrations observed at most sites in 1998.

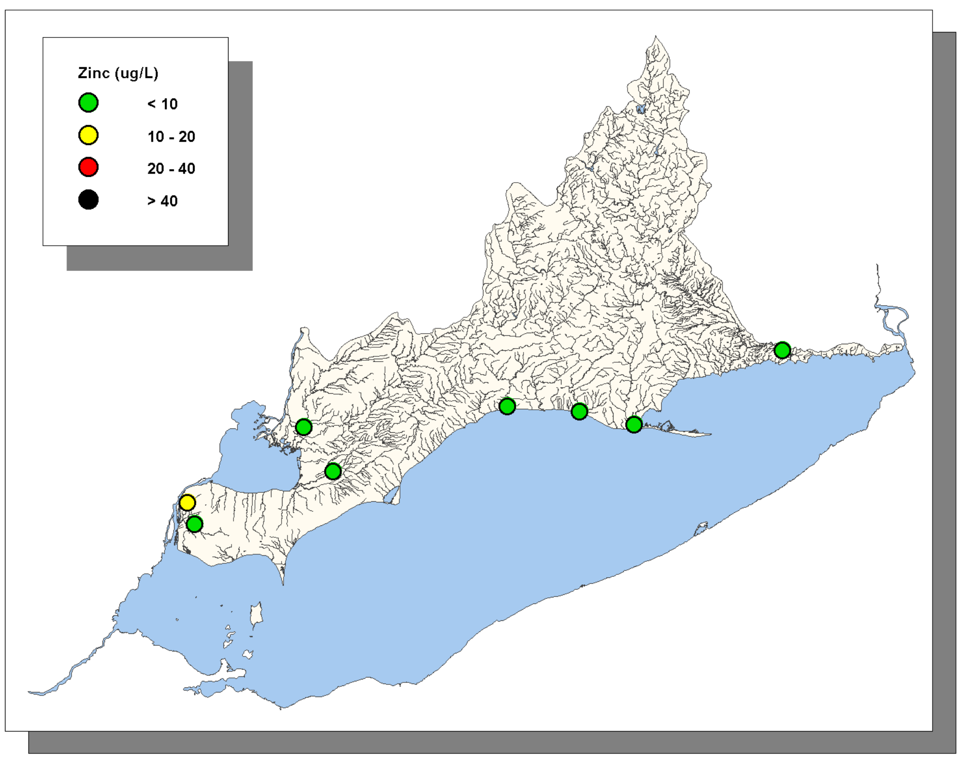

Figure 2.4.4: Median zinc concentration from 1998/99 Tributary Toxics monitoring.

Lake St. Clair and the western basin of Lake Erie (where eutro-

phication and increased algal productivity have historically been a problem) tend to have the lowest water clarity, measured as secchi depth. Total phosphorus concentrations are relatively uniform around the lake and are generally below the open lake guideline of 20 µg/L. Similar to phosphorus, nitrate concentrations are relatively uniform around the lake and are generally below 300 µg/L. Nitrate concentrations are well below Ontario Drinking Water Objectives.

Zebra mussels have become a dominant member of the benthic community in Lake Erie. The data reveal a ubiquitous distribution in the nearshore with peak densities in excess of 10 000 individuals/m^2. The potential of the exotic zebra mussel to alter the Great Lakes ecosystem has led to a myriad of research effort in recent years, particularly in Lake Erie.

The Millbrink Index uses benthic invertebrate species composition and density data to evaluate trophic status. The index indicates that meso-oligotrophic (low-to-medium nutrient) conditions exist throughout the Lake Erie nearshore except for the western basin and the mouths of the Thames and Grand Rivers where eutrophic (high nutrient) conditions remain.

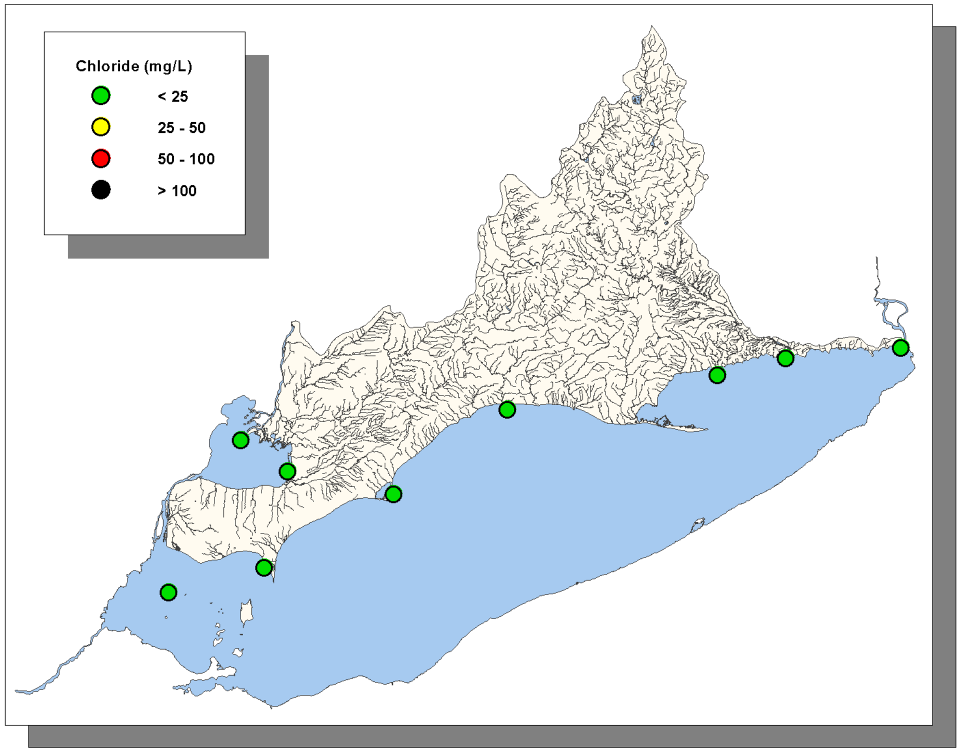

Figure 2.4.5: Median chloride concentration at Lake Erie Index Stations (1998).

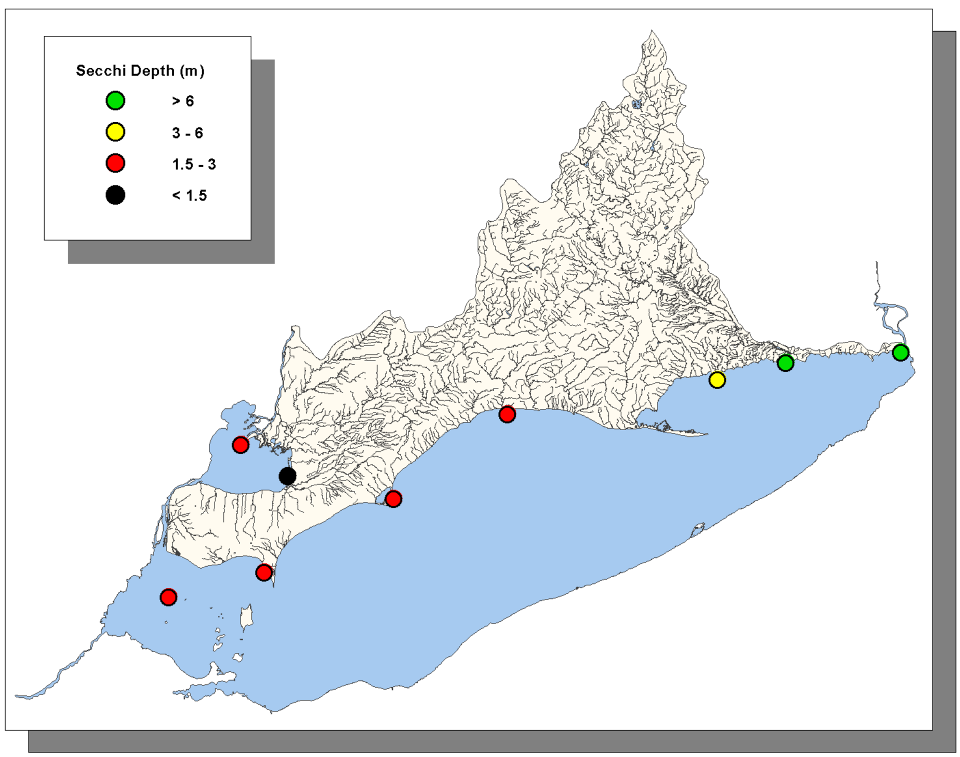

Figure 2.4.6: Median secchi depth (turbidity) at Lake Erie Index Stations (1998).

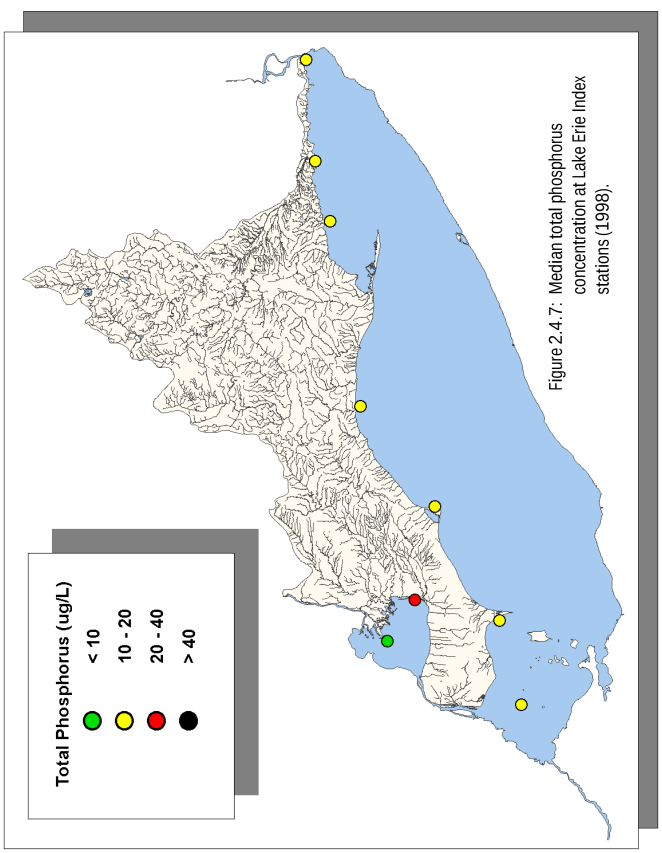

Figure 2.4.7: Median total phosphorus concentration at Lake Erie Index stations (1998).

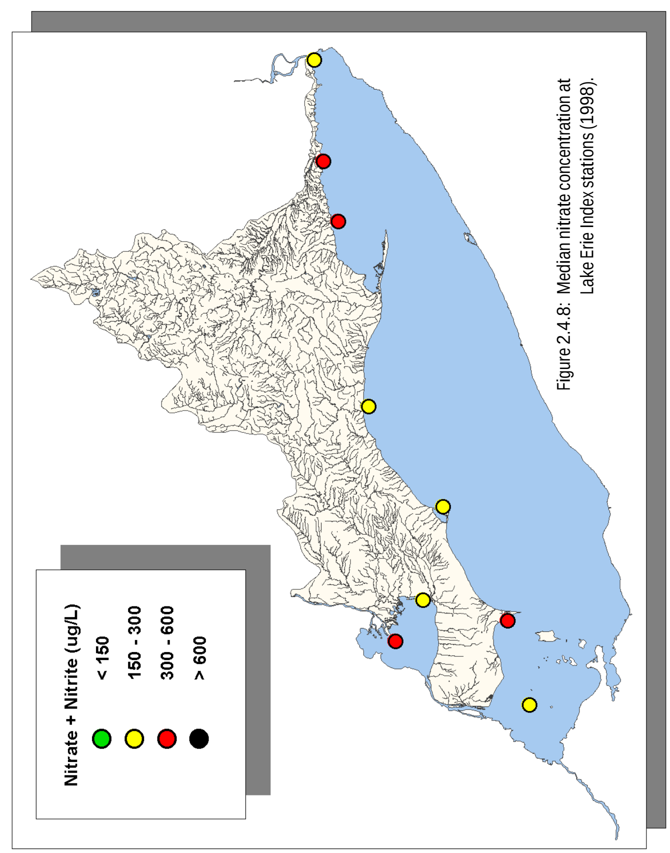

Figure 2.4.8: Median nitrate concentration at Lake Erie Index stations (1998).

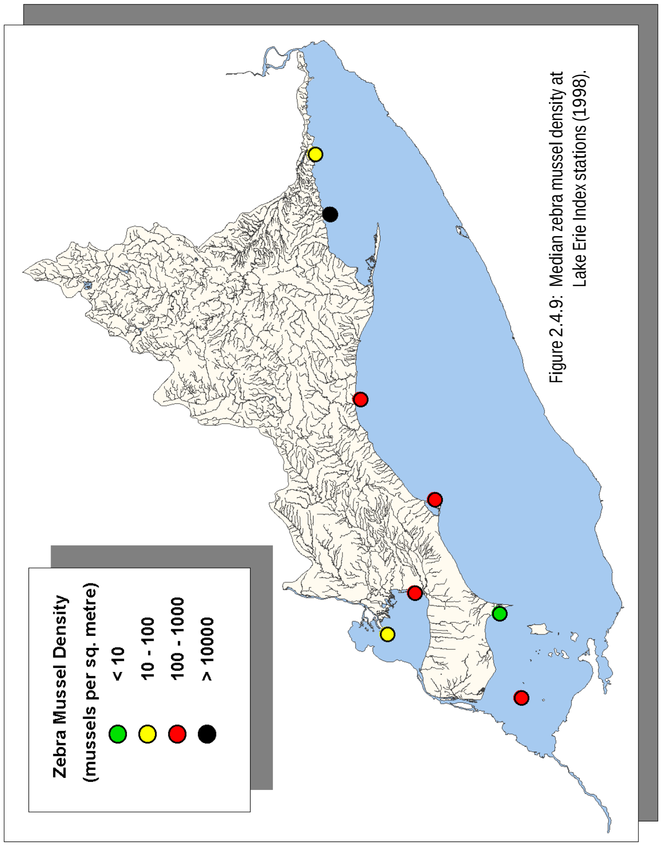

Figure 2.4.9: Median zebra mussel density at Lake Erie Index stations (1998).

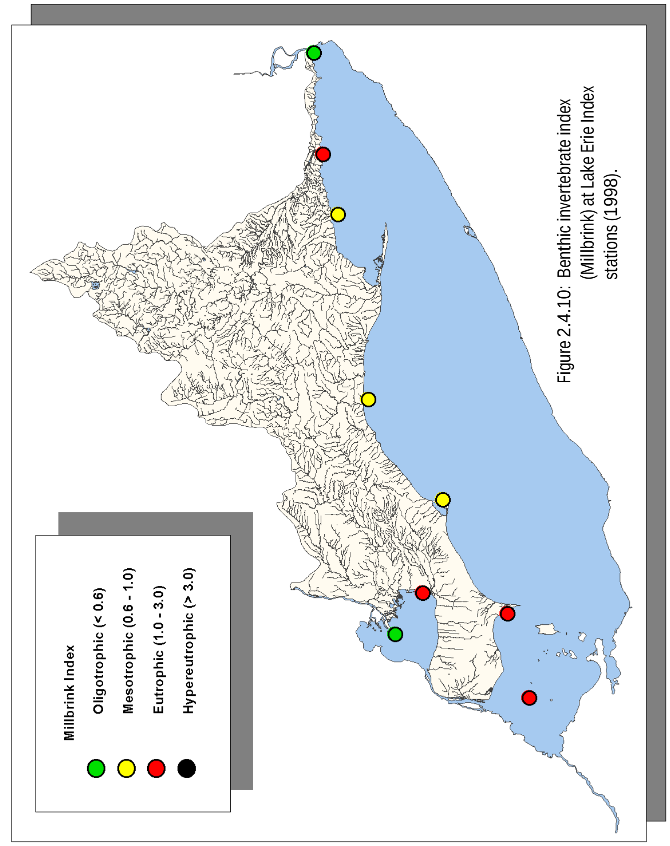

Figure 2.4.10: Benthic invertebrate index (Millbrink) at Lake Erie Index stations (1998).

2.4.3 Lake Erie Water Intake Monitoring

Water intake monitoring data are well-suited for evaluating long-term water quality trends in the nearshore waters of Lake Erie. A procedure, similar to that used to evaluate trends in the PWQMN data, was applied to the water intake data yielding a comparison of the period 1980 to 1982 with the period 1996 to 1998. Trends in chloride, total phosphorus and nitrate were examined by comparing mean concentrations (with 95% confidence intervals) for the two time periods.

Chloride concentrations between the early 1980s and late 1990s have decreased significantly at most of the water intakes, despite the increase documented in Lake Erie tributaries. The apparent contradiction reflects the tendency for ambient conditions in Lake Erie to be influenced by flows from the St. Clair/Detroit River corridor where chloride loading from industrial practices have declined significantly. The exception to the declining trend is the Dunnville water intake, where chloride loading from the Grand River can influence a greater proportion of the nearshore.

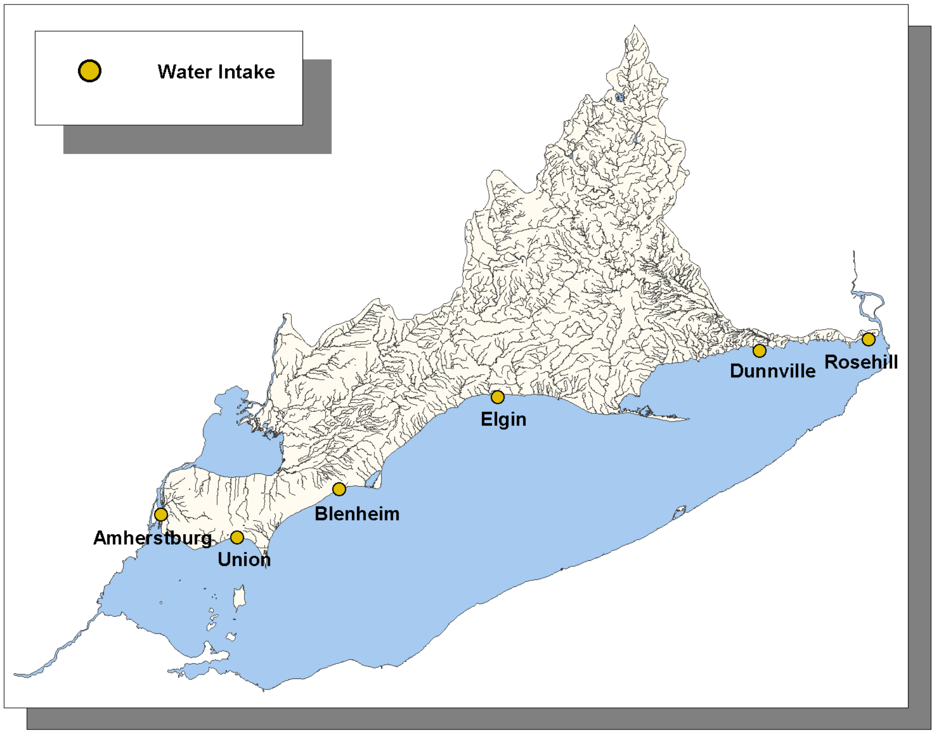

Figure 2.4.11: Water intake monitoring locations in Lake Erie.

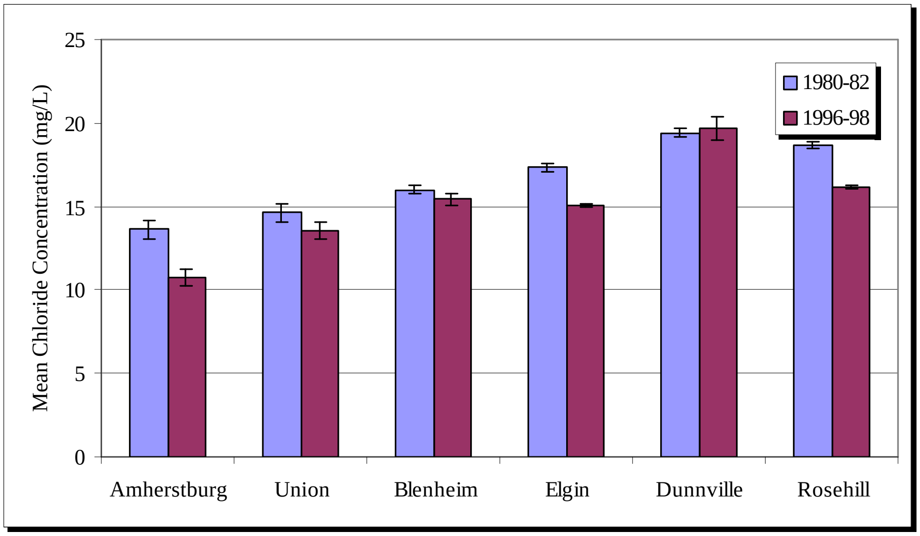

Figure 2.4.12: Trends in mean chloride concentration (with 95% confidence intervals) at Lake Erie water intakes.

Phosphorus concentrations have decreased significantly at half of the water intakes monitored over this period despite increases in urbanization. The declining trend is attributable to the success of phosphorus loading reductions at municipal point sources throughout the Great Lakes basin. Recent reductions in phosphorus (and increase in water clarity) may also be linked to the effectiveness of the zebra (and quagga) mussel at filtering organic matter and removing nutrients from the water column.

Unlike phosphorus, nitrate concentrations have not decreased at all; in fact, they have increased significantly. Nitrate has not been targeted for point source load reductions similar to phosphorus, so increased loads from STPs, as well as agricultural inputs, are likely contributing to a gradual steady increase in ambient concentrations. Nitrate concentrations in Lake Erie are not of concern relative to human water use criteria.

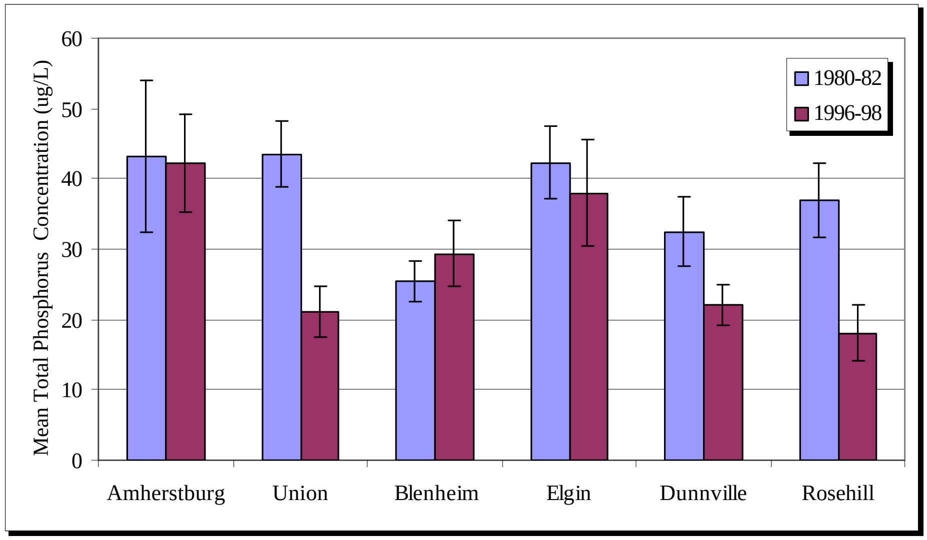

Figure 2.4.13: Trends in mean total phosphorus concentration (with 95% confidence intervals) at Lake Erie water intakes.

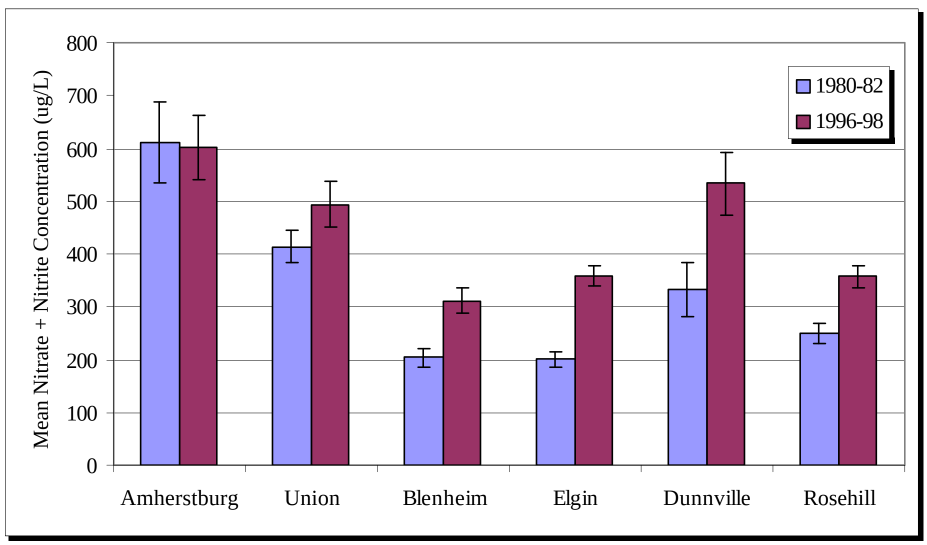

Figure 2.4.14: Trends in mean nitrate concentration (with 95% confidence intervals) at Lake Erie water intakes.

2.5 Lake Erie Nearshore Sediment Quality Monitoring

Although the detection of trace metals and organics may be easier in sediment samples than in water, discerning spatial and temporal trends, and the effects of pollution sources can be difficult. In nearshore and harbour areas sediment composition (and hence quality) can be highly variable. Sediment can be resuspended and transported by storms and boat traffic so that conditions within a harbour can vary seasonally. Biological activity can disturb sediment strata obscuring inferences regarding year-to-year trends. In some areas this patchy distribution can be observed on a scale of less than one metre during a sediment survey.

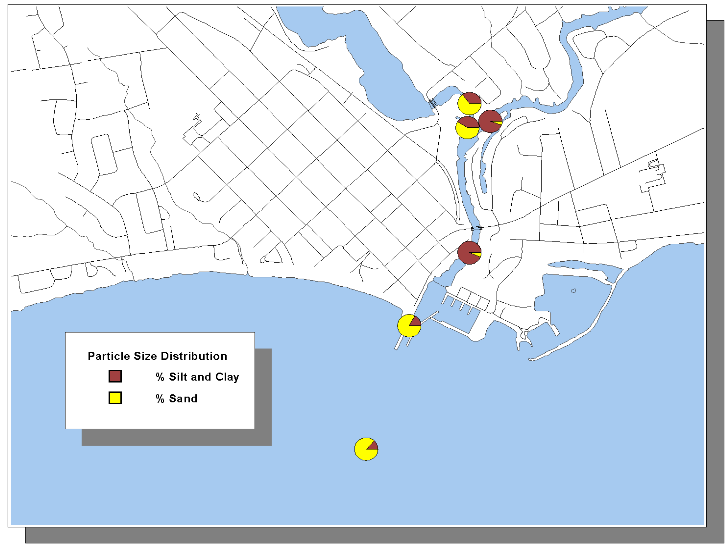

Figure 2.5.1: Variability in sediment particle size at Port Dover (1998).

Local variability in sediment composition has been illustrated by mapping particle size distribution at Port Dover. Within the harbour, sediment composition varies from predominantly silt and clay (fine-grained) to predominantly sand (coarse-grained). Due to local variability in sediment composition, as illustrated, it is inappropriate to characterize a nearshore zone by pooling contaminant concentrations for several locations. Methods are available for minimizing particle size effects on sediment chemistry data, however; these techniques are not illustrated in this report. The following maps depict maximum sediment concentration for selected indicators from Lake Erie Reconnaissance Monitoring and Index Station monitoring. Screening for maximum concentrations provides a means of identifying potentially contaminated sediments that occur around the lake as the result of proximity to current and historical sources.

Concentrations of PAHs and PCBs found in Lake Erie sediment are typically less than the Provincial Sediment Quality Guidelines Lowest Effect Level. At this level of contamination the sediment is considered clean to marginally polluted and is not likely to have an affect on the majority of sediment-dwelling organisms. Maximum concentrations of PAHs at Leamington, Wheatley Harbour, Port Dover (Lynn River), lower Thames River and upper St. Clair River exceed the Lowest Effect Level guideline, however; the concentrations are relatively low compared to areas with known contamination. Maximum concentrations exceeding the Severe Effect Level guideline are evident in the Detroit River resulting from industrial sources and highly-urbanized catchments in the St. Clair/Detroit River corridor.

Elevated concentrations of PCBs in the western basin can also be attributed to downstream transport from urban/industrial sources in the St. Clair/Detroit River corridor. Concentrations exceeding the Severe Effect Level guideline were observed in the upper St. Clair River. Elevated concentrations also exist in Wheatley Harbour where accumulations of organic waste from fish processing operations have been identified as a mechanism of PCB contamination in sediment.

Efforts to reduce phosphorus loads to surface water have been effective; however, Lake Erie sediment continues to be enriched with the nutrient phosphorus. Total phosphorus concentrations exceeding the Lowest Effect Level guideline of 600 µg/g exist at all locations with the exception of the St. Clair River and upper Lake St. Clair. Prominently elevated total

phosphorus concentrations were observed at Port Dover (Lynn River), Nanticoke Harbour and the mouth of the Grand River. Concentrations exceeding the Severe Effect guideline of 2000 µg/g exist in Wheatley Harbour where a documented history of water quality problems contributed to the designation of the harbour as an international Area of Concern.

Maximum sediment mercury concentrations are below the Lowest Effect Level guideline of 0.2 µg/g throughout the central and eastern basins of Lake Erie. Mercury concentrations exceeding the PSQG Severe Effect Level are evident in the upper St. Clair River. Mercury contamination in the St. Clair/ Detroit River corridor is directly related to historical industrial sources and the downstream transport of mercury to the western basin of Lake Erie is evident. A majority of sport fish consumption advisories in Lake St. Clair and the St. Clair and Detroit Rivers are the result of mercury contamination.

Sediment lead and zinc concentrations are low (relative to areas with known contamination) with no exceedances of the PSQG Severe Effect Level. Concentrations are either at, or slightly above, their respective Lowest Effect Level or are comparable to background concentrations.

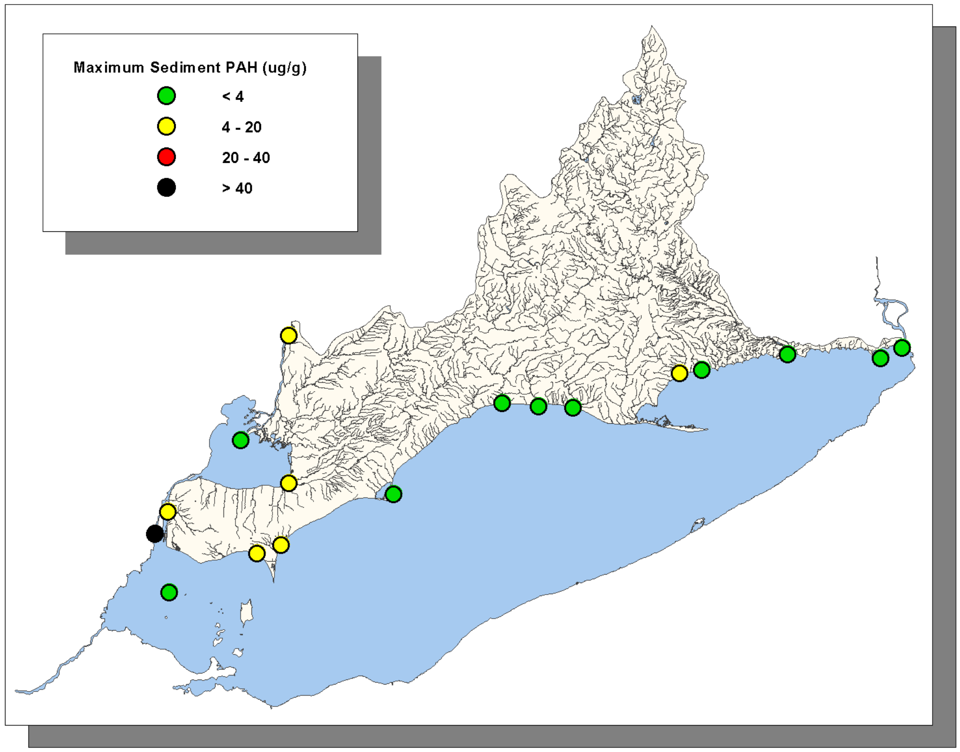

Figure 2.5.2: Maximum concentration of total PAHs at Lake Erie Index and Reconnaissance Stations (1994-1998).

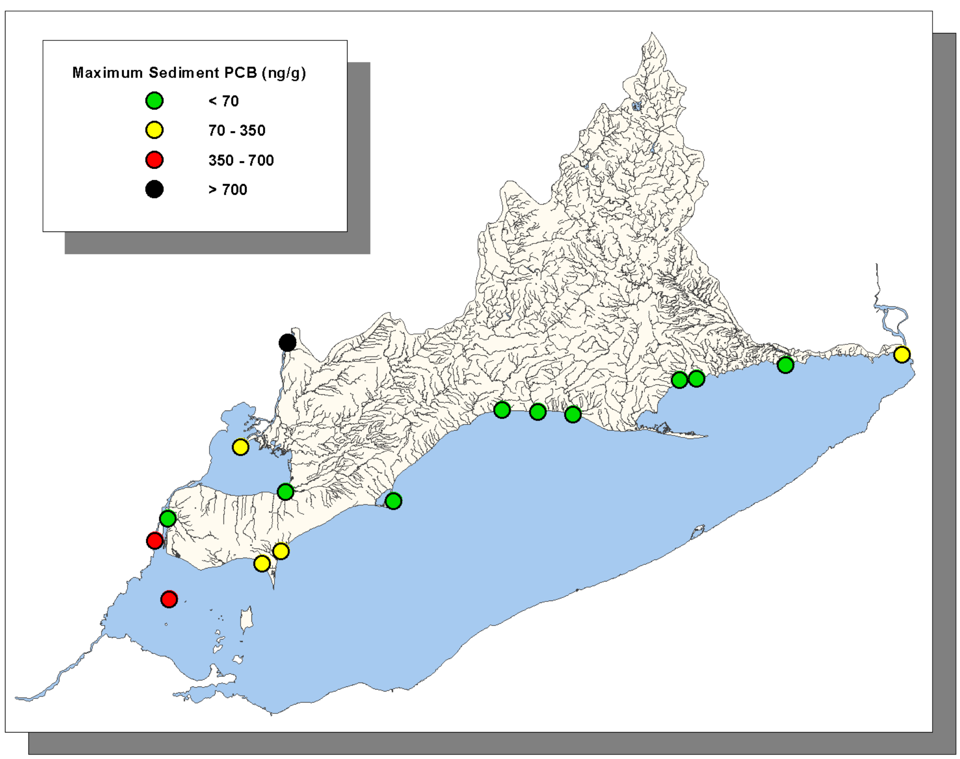

Figure 2.5.3: Maximum concentration of total PCBs at Lake Erie Index and Reconnaissance Stations (1994-1998).

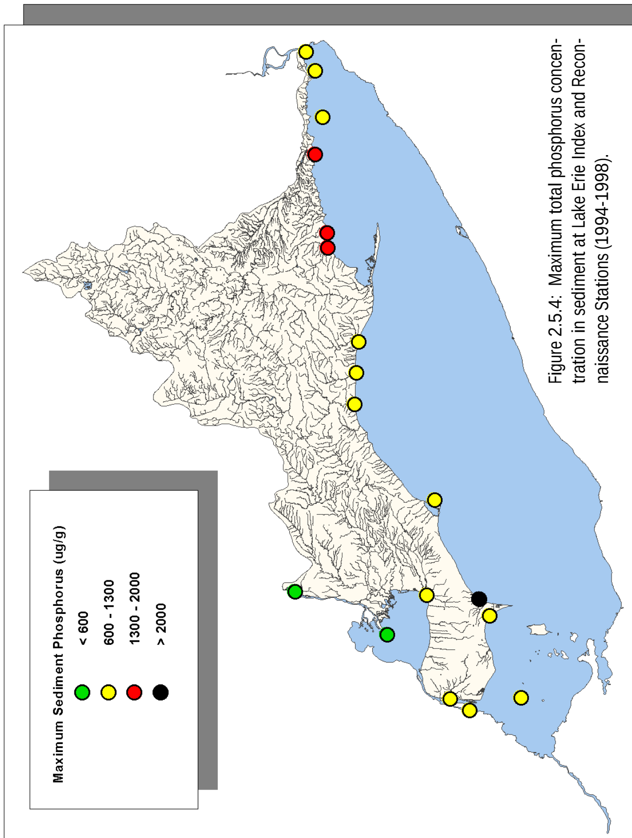

Figure 2.5.4: Maximum total phosphorus concentration in sediment at Lake Erie Index and Reconnaissance Stations (1994-1998).

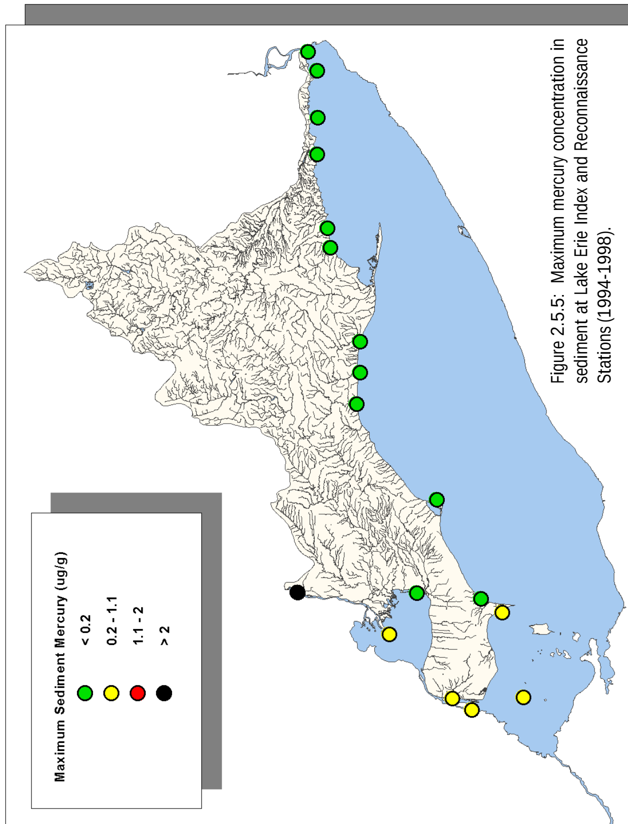

Figure 2.5.5: Maximum mercury concentration in sediment at Lake Erie Index and Reconnaissance Stations (1994-1998).

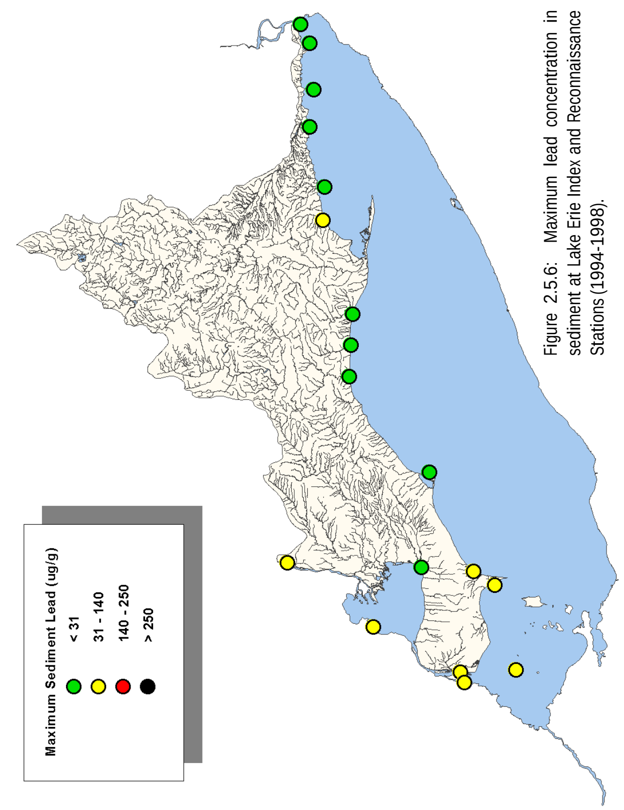

Figure 2.5.6: Maximum lead concentration in sediment at Lake Erie Index and Reconnaissance Stations (1994-1998).

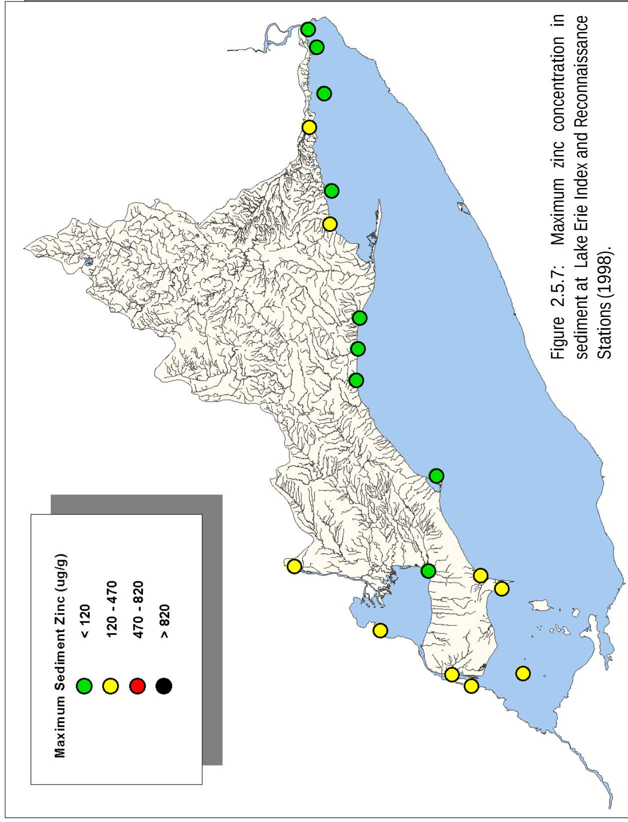

Figure 2.5.7: Maximum zinc concentration in sediment at Lake Erie Index and Reconnaissance Stations (1998).

2.6 Juvenile Fish Monitoring

Contaminants such as trace metals and organics have low solubility in water and tend to adsorb to sediment or accumulate in biological tissue. Trace organics such as PCBs and organochlorine pesticides (e.g. DDT, lindane, chlordane) are of concern due to their persistence and their potential to bioaccumulate through the food web into predatory fish and subsequently into fish-eating birds and mammals (including humans). For this reason, analysis of biological tissue is a useful means of augmenting water and sediment sample analysis. This has the advantage of determining an actual biological response to contaminant exposure, but is one step further removed from the contaminant source spatially and temporally. Monitoring for juvenile fish, typically young-of-the-year spottail shiners, is a good compromise in that their geographical range is limited relative to adult top-predator species and the exposure period is known.

Results of sampling over the period 1990 to 1998 have been summarized for total PCBs and total DDT (i.e. the sum of DDT and metabolites) and median concentrations for each sampling area are presented to illustrate typical conditions in the Lake Erie basin. The results are compared with equivalent data for the period 1975 to 1980 to illustrate the general trend.

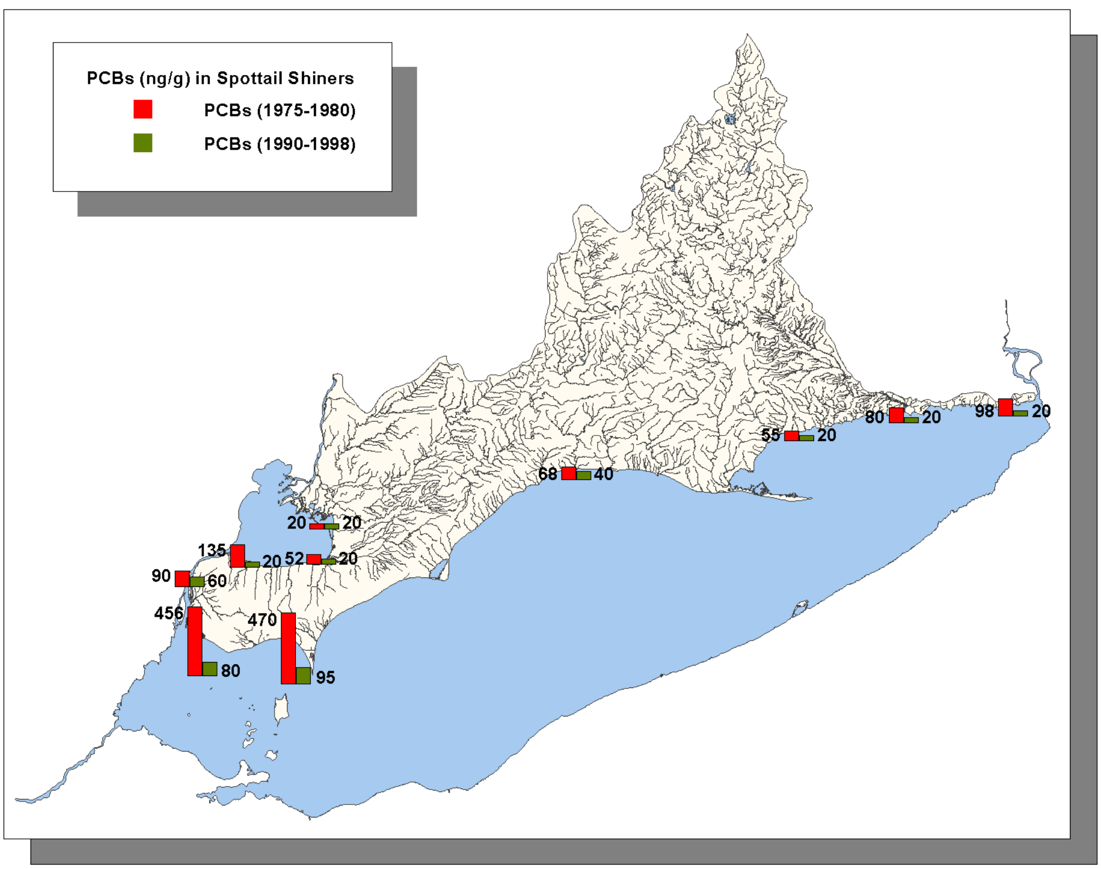

Figure 2.6.1: Comparison of median PCB concentration in Spottail Shiners between the period 1975 to 1980 and the period 1990 to 1998.

The results show uniformly low DDT residues in juvenile fish in Lake St. Clair, the Detroit River and Lake Erie. Concentrations of PCBs are also low at the same locations. At two locations in the western basin of Lake Erie the PCB concentrations approach, but do not exceed, the International Joint Commission guideline of 100 ng/g for the protection of fish-eating birds and mammals. Large declines in DDT and PCB residues between the late 1970s and the mid 1990s are evident.

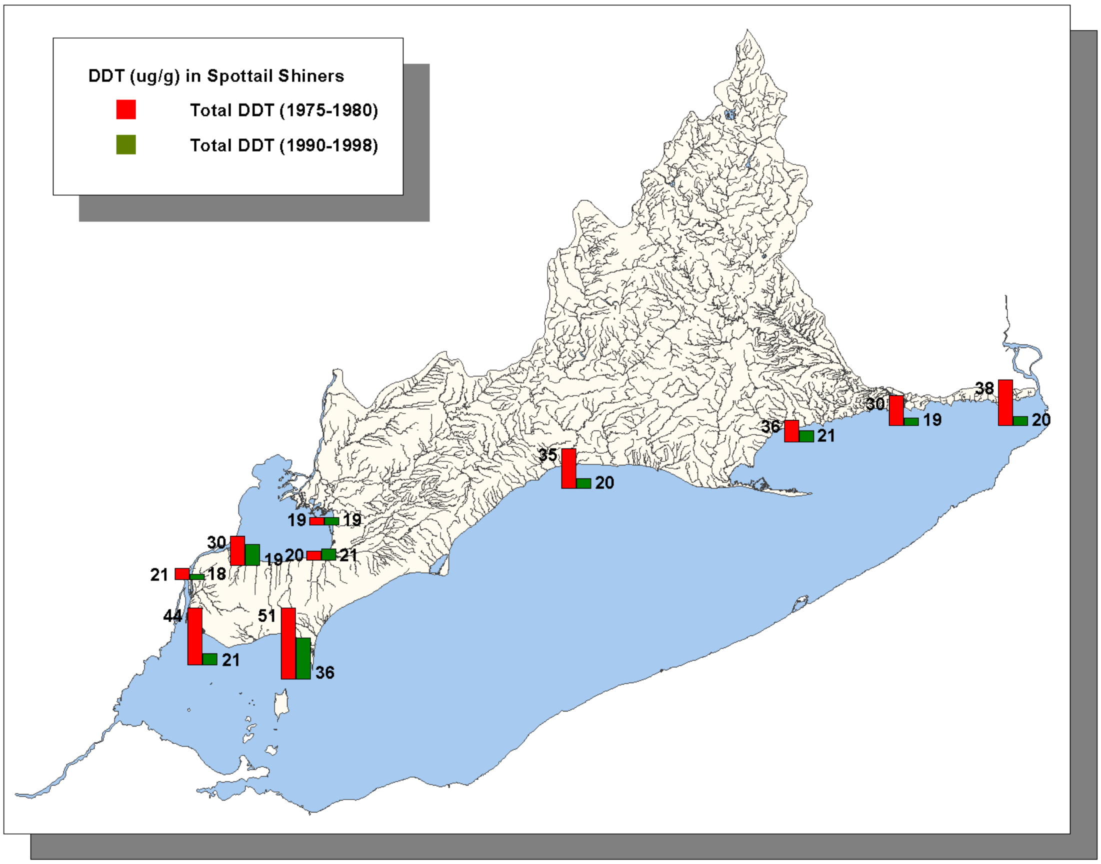

Figure 2.6.2: Comparison of median DDT concentration in Spottail Shiners between the period 1975 to 1980 and the period 1990 to 1998.

3.0 Program Contacts for Additional Information

This report was prepared to summarize the range of surface water monitoring programs undertaken by the Environmental Monitoring and Reporting Branch in the Lake Erie basin. The data summaries are presented as examples of the types of information available. For additional information regarding the monitoring programs consult the following list of contacts:

Program/Project	Contact	Telephone
Stream Water Quality	Aaron Todd	(416) 235-6240
Streamflow Monitoring	Brian Whitehead	(416) 235-6256
Great Lakes Index Stations	Todd Howell	(416) 235-6225
Great Lakes Reconnaissance: Shoreline Mapping	Todd Howell	(416) 235-6225
Great Lakes Reconnaissance: Harbour Screening	Lisa Richman	(416) 235-6257
Great Lakes Tributary Toxics	Mary Wilson	(416) 235-6238
Great Lakes Water Intake Biomonitoring	Lynda Nakamoto	(416) 235-5811
Juvenile Fish Toxics Biomonitoring	Alan Hayton	(416) 327-7470
Sport Fish Contaminants	Alan Hayton	(416) 327-7470
Inland Lake Monitoring (Lake Partner Program)	Wolfgang Scheider	(416) 327-6535

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